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A GUIDE TO THE GET MODEL

by

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This is a manual detailing the structure of the applied general equilibrium trade (GET) model of the Canadian economy developed under contract for the Department of Finance. The author is indebted to the comments and conversations of those involved in the trade modelling project within the Department of Finance. He wishes to thank, and acknowledge the assistance of, David Cox, François Delorme, John Lester, Raynald Létourneau, Sandy Moroz, and Benoît Robidoux.

Working papers are intended to make analytic work undertaken in the Department of Finance available to a wider readership. They have received only limited evaluation and do not necessarily reflect the views of the Department of Finance. Comments on the working papers are invited and may be sent to the author(s). They are circulated in the language of preparation.

ABSTRACT

This study is one of a series of technical papers that provide details of the Department of Finance's analysis of the impact of Canada-U.S. Free Trade. Results of the Department of Finance analysis were summarized in the document The Canada-U.S. Free Trade Agreement: An Economic Assessment. This document explains the structure and coding of the general equilibrium trade model, denoted by the acronym GET, which was used to analyze the long-term economic impact of the Canada-U.S. Free Trade Agreement. GET is a large scale numerical model which focuses on the role of relative prices in factor and commodity markets in determining the allocation of resources. The general equilibrium aspects of the model are quite conventional but the explicit modelling of imperfect competition and plant-level scale economies in manufacturing industries is a novel feature of GET. An earlier version of the GET model is described in Trade, Industrial Policy and Canadian Manufacturing by Richard Harris (with David Cox) published by the Ontario Economic Council in 1983. This version of the model is based on more recent data on the structure of the Canadian economy. It also provides more sectoral detail and incorporates updated estimates of key model parameters such as trade price elasticities and economies of scale.

RÉSUMÉ

Cette étude fait partie d'une série de rapports techniques qui documente l'analyse de l'impact du libre-échange canado-américain effectué par le ministère des Finances. Les résultats de cette analyse sont résumés dans le document; Accord de libre-échange entre le Canada et les États-Unis: une évaluation économique. Ce document explique la structure et la codification d'un modèle d'équilibre général appliqué au commerce international, ayant l'acronyme GET, et qui a été utilisé pour analyser l'impact économique à long-terme de l'accord de libre-échange canado-américain. GET est un modèle numérique multi-secteurs qui utilise les prix relatifs sur les marchés des facteurs et des biens comme mécanisme d'allocation des ressources. Les aspects d'équilibre général du modèle sont relativement conventionels, mais la modèlisation explicite de la compétition imparfaite et des économies d'échelle au niveau de l'établissement dans les industries manufacturières est l'aspect novateur de GET. Une ancienne version du modèle GET est décrite dans Trade, Industrial Policy and Canadian Manufacturing de Richard Harris (avec David Cox) publié par le conseil économique de l'Ontario en 1983. La présente version du modèle est basée sur des données plus récentes de la structure de l'économie canadienne, sur une classification industrielle plus fine et utilise de nouveaux estimés des paramètres clés tels que les élasticités-prix d'exportations et d'importations et les économies d'échelle.

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Sommaire

Introduction au guide de GET

1.1 Introduction

Ce guide explique la structure et la codification d'un modèle d'équilibre général appliqué au commerce international ayant l'acronyme GET et qui est utilisé au ministère des Finances aux fins d'analyse de politiques. GET a d'abord été conçu pour l'analyse des négociations sur la libéralisation des échanges bilatéraux entre le Canada et les États-Unis, mais il se prête à des utilisations qui vont au-delà de cet objectif initial. Le modèle GET entre dans la catégorie des modèles d'équilibre général, appellation qui s'est imposée au cours des années 1980. Il s'agit d'un modèle numérique multi-secteurs qui utilise l'ajustement des prix relatifs sur les marchés des facteurs et des biens comme mécanisme principal d'ajustement économique, en conjugaison avec des changements de la structure industrielle. Le trait distinctif des modèles d'équilibre général calculables, ou modèles EGC, est que leurs fondements théoriques en ce qui concerne les hypothèses sur les préférences, la technologie, les ressources et les politiques gouvernementales sont habituellement assez explicites. Contrairement à beaucoup de modèles macroéconomiques, les modèles EGC n'ont pas pour point de départ une forme réduite d'offre et de demande ou des conditions d'équilibre : tous ces éléments sont dérivés d'hypothèses microéconomiques plus fondamentales. Le modèle GET entre entièrement dans la catégorie de ces modèles EGC.

Ce guide s'adresse à deux catégories de lecteurs. Il a été rédigé pour ceux qui travaillent actuellement sur le modèle ou qui ont entrepris de modifier ses structures. Il s'adresse également à ceux qui cherchent à comprendre le fonctionnement du modèle et l'exécution des programmes de base. Certaines parties du guide seront plus intéressantes que d'autres pour certains lecteurs. La structure théorique du modèle est exposée en détail aux chapitres 2 et 4. La description des programmes informatiques de base est présentée aux chapitres 5 et 6. Le chapitre 3, qui décrit les résultats du modèle, intéressera ceux qui utilisent cet élément du modèle, mais qui ne cherchent pas particulièrement à connaître en détail les procédures empiriques et les aspects mathématiques de la résolution du modèle. L'Annexe A.1 décrit la construction des flux de revenu et de production à partir de tableaux entrées-sorties, conformément à la classification industrielle du modèle. Cette annexe intéressera ceux qui travaillent au calibrage, qu'il s'agisse de versions ultérieures de GET ou de modèles similaires.

La compréhension d'une grande partie de ce guide suppose une bonne connaissance des modèles économiques et des procédures de comptabilité économique. La théorie qui sous-tend le modèle s'appuie sur la théorie traditionnelle des échanges et fait également appel aux travaux récents sur la concurrence imparfaite et le commerce international tels qu'ils ont été résumés, par exemple, par Helpman et Krugman (1985). La compréhension du chapitre 5 sur le calibrage exige des lecteurs une connaissance pratique des procédures de calibrage des modèles d'équilibre général calculables. On retrouve une bonne présentation de ces procédures dans Shoven et Whalley (1984) et Whalley (1985).

Ceux qui exploiteront le modèle dans tous ses aspects doivent se munir d'une copie du code fortran, à la fois pour l'algorithme de solution (PILOT) et pour le programme de calibrage (TEST), lorsqu'ils aborderont les chapitres pertinents. Une analyse efficace des modèles d'équilibre général appliqués exige qu'on puisse aisément passer des équations algébriques, représentant la théorie économique pertinente, au programme fortran qui met cette théorie en pratique, et vice versa. Habituellement, cette aptitude ne vient qu'avec une expérience considérable.

Le seul autre but de ce chapitre est de fournir au lecteur non initié aux techniques de modélisation économique une description de GET, ses principales caractéristiques et les aspects qui le distinguent d'autres modèles de la même catégorie. Les sections 1.2 et 1.3 présentent le modèle en des termes non techniques. La section 1.4 discute des modèles EGC en tant qu'outils d'analyse de politiques ainsi que certaines questions que GET est censé résoudre.

1.2 Sommaire des caractéristiques d'équilibre général de GET

Cette section fournit une brève description du modèle d'équilibre général GET. On peut trouver une description plus détaillée du modèle GET original dans Harris (1984b); la version actuelle est exposée en détail au chapitre 2. Par souci de brièveté, ce sommaire insistera sur les aspects du modèle qui sont relativement novateurs.

Tous les aspects d'équilibre général du modèle sont assez conventionnels. GET n'est pas un modèle d'équilibre général complet étant donné que les pays étrangers, tant les États-Unis que le Reste du monde (RDM), sont représentés par des prix d'importation exogènes et par une série d'équations de demande d'exportation. L'accent est mis sur l'équilibre au sein de l'économie canadienne. La concurrence existe sur les marchés des facteurs de production et sur les marchés des produits dans les secteurs non-manufacturiers. Les prix sont flexibles et le plein emploi est supposé décrire adéquatement un équilibre de long terme. Du côté de la consommation, la demande nationale est générée par un seul consommateur qui maximise une fonction d'utilité sous contrainte budgétaire. L'utilité découlant des diverses catégories de biens est décrite par une fonction Cobb-Douglas. À l'intérieur de chaque catégorie de biens, l'hypothèse d'Armington est maintenue : les biens provenant des États-Unis, du RDM et les biens nationaux sont des substituts imparfaits tel que décrit par une fonction CES appliquée à ces trois produits.

Les fonctions d'exportation vers le RDM et aux États-Unis sont générées par un consommateur dans chaque région ayant un revenu exogène et pour qui les biens nationaux, les biens canadiens et les autres biens sont des substituts imparfaits. Dans le cas des équations de demande d'importation des États-Unis, cette spécification permet de quantifier l'ampleur du détournement et de la création de commerce. La réduction des tarifs bilatéraux, à prix constants, entre le Canada et les États-Unis provoquera le renversement du trafic des importations américaines vers les produits canadiens. Dans le modèle, le Canada influence les prix sur ses marchés d'exportation, mais il n'influence pas les prix sur ses marchés d'importation.

L'hypothèse voulant que le pays national influence les prix sur ses marchés d'exportation mais non les prix sur ses marchés d'importation est problématique. Bien que dans le cas du Canada cette hypothèse ait un certain support empirique (voir Appelbaum et Kohli 1979), il reste manifestement un problème d'ordre logique. Supposons que l'industrie mondiale du machin soit caractérisée par une concurrence imparfaite. Les firmes nationales peuvent varier leurs prix; mais, dans le cadre du modèle, les actions de ces firmes n'influencent pas les prix fixés par les firmes étrangères concurrentes, qu'il s'agisse de firmes américaines ou du RDM. Le principal argument à la défense de cette hypothèse est que les firmes nationales font face à une importante industrie mondiale produisant un substitut proche mais imparfait. Partant de l'hypothèse que la part totale du marché mondial du machin détenue par les entreprises nationales est petite, la réaction de l'industrie mondiale en réponse à des changements de prix décidés par les firmes nationales est considérée comme étant assez faible pour qu'on n'en tienne pas compte.

Du côté de la production, les firmes utilisent le capital, le travail et les biens intermédiaires pour produire l'output de l'industrie. Les inputs intermédiaires étrangers et nationaux sont considérés comme des substituts imparfaits. Du côté de l'output, chaque firme produit un seul produit, et dans une seule branche d'activité.

Le secteur manufacturier comprend les industries qui sont potentiellement non compétitives. Les industries réglementées ne sont pas explicitement modélisées comme étant non compétitives. Chaque industrie non compétitive est formée d'un nombre endogène de firmes représentatives disposant chacune de la même technologie. La technologie est caractérisée par un coût fixe; la mise en place d'une firme exige un volume fixe de capital et de travail. Les coûts variables unitaires de long terme sont indépendants de la production; il ne sont fonction que du prix des inputs et des paramètres liés à la technologie. La courbe de coût moyen à donc une pente négative et suit une courbe asymptotique par rapport aux coûts variables unitaires. Puisque les rendements croissants à l'échelle existent au niveau de la production, l'utilisation efficace des ressources est influencée par l'échelle de production de la firme. GET modélise explicitement la détermination de l'échelle de la firme, tout comme l'entrée et la sortie des firmes dans les industries non compétitives. Dans les industries compétitives, il n'y a pas de coûts fixes et on utilise une spécification conventionnelle de rendements constants. Les formes fonctionnelles, mais non les paramètres, sont les mêmes que celles qui sont utilisées pour décrire le coût variable dans les industries non compétitives.

La main-d'oeuvre est homogène et mobile entre les industries. Le capital est homogène et mobile entre les industries et entre les pays. Par ailleurs, l'offre de capital est supposée être parfaitement élastique au prix mondial. L'offre de main-d'oeuvre est inélastique et provient des consommateurs nationaux. Le revenu intérieur est tiré du travail et du capital détenu par les consommateurs nationaux ainsi que des transferts nets des gouvernements. Compte tenu de la mobilité du capital, l'équilibre de la balance des paiements est un concept de balance des comptes courants: l'excédent commercial doit être égal aux paiements pour l'utilisation du capital étranger.

Les industries manufacturières sont divisées en deux groupes : les industries dont la production est en concurrence avec les produits importés et les industries orientées vers l'exportation. Il existe des économies d'échelle au sein de ces dernières industries, mais on présume que les firmes nationales font face à un marché mondial hautement compétitif. La structure de marché de cette industrie mondiale est expliquée par la théorie des marchés contestables de Baumol et al (1982).

Le concept d'équilibre utilisé dans le cas des industries en concurrence imparfaite dont les produits sont en concurrence avec les importations est une version modifiée de l'approche Cournot-Chamberlin au niveau de l'industrie. Deux hypothèses sont utilisées pour décrire le comportement des firmes en matière de détermination des prix. La première est une hypothèse de détermination des prix en concurrence monopolistique (MCH) avec des courbes de demande perçue. La règle de Lerner est utilisée pour déterminer les prix en fonction de l'élasticité de la courbe de demande perçue. On obtient cette élasticité en supposant que chaque firme exécute une expérience hypothétique de statique comparée dans laquelle elle change ses prix et observe les changements de demande sous l'hypothèse que la demande de l'industrie est également partagée entre toutes les firmes domestiques. L'élasticité de la demande perçue par la firme est ainsi liée aux paramètres sous-jacents de la technologie, aux préférences et aux demandes d'exportation. Un changement de cette élasticité entraînera une modification de la marge bénéficiaire prise sur le coût marginal.

L'autre hypothèse de détermination des prix est justifiée par le modèle Eastman-Stykolt (1967) d'oligopoles protégés au sein de petites économies ouvertes. L'idée de base est que les firmes nationales fixent leurs prix aux alentours d'un point central collusoire déterminé par le prix mondial majoré des tarifs qui s'appliquent aux biens étrangers en concurrence avec les biens nationaux. On suppose, dans le modèle décrit dans ce document, que l'industrie américaine est la concurrente principale de l'industrie canadienne. La réduction des droits de douane canadiens qui s'appliquent aux importations américaines fournit un mécanisme direct de réduction des prix intérieurs en réponse à la libéralisation des échanges entre le Canada et les États-Unis.

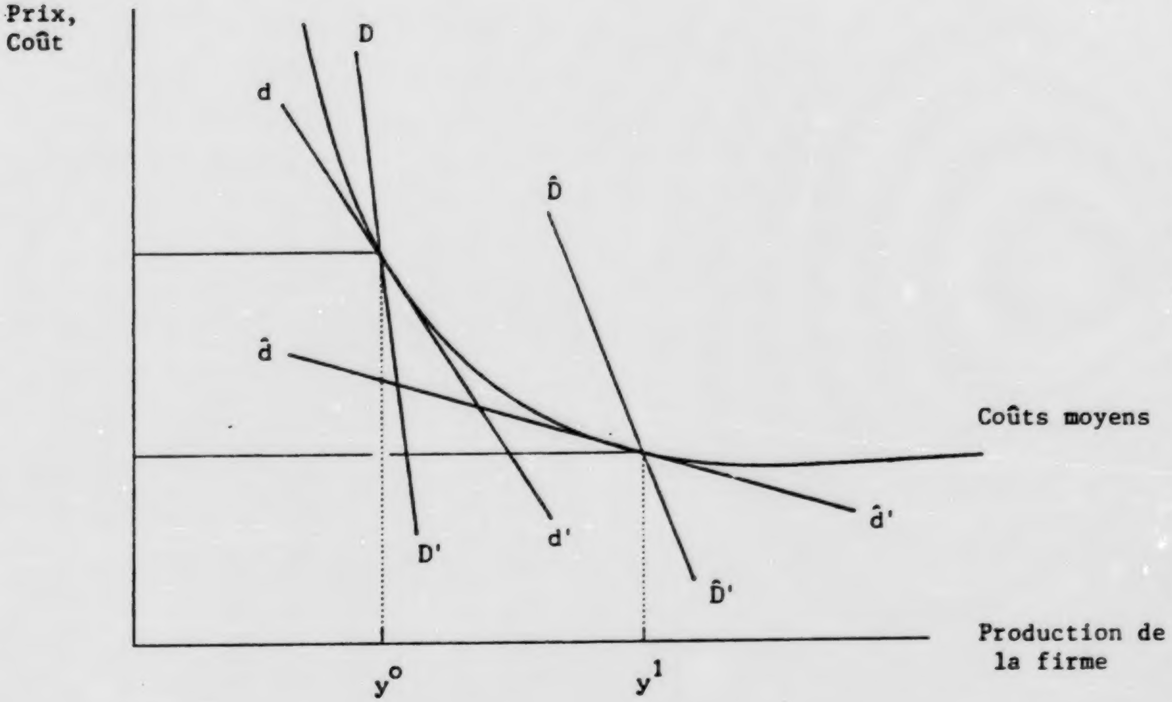
La règle de détermination des prix utilisée est un amalgame de MCH et ESH, une pondération exogène ayant été accordée à chacun de ces concepts. Il est manifeste qu'une telle approche en matière de détermination des prix est quelque peu ad hoc, mais elle a le mérite d'être empiriquement malléable. On ne suppose aucune barrière à l'entrée et à la sortie des firmes dans les industries non compétitives. Toutes les barrières à l'entrée autres que les coûts fixes ne sont pas prises en compte. Un équilibre à long terme est caractérisé par des profits économiques nuls dans toutes les industries et les prix sont égaux aux coûts moyens.

Au niveau de l'équilibre général, les variations de productivité résultant des changements d'échelle de production se répercutent sur les salaires et les prix. Au niveau agrégé, l'évolution du revenu réel, du volume et des termes de l'échange, ainsi que des salaires réels sont les agrégats les plus affectés par la libéralisation des échanges. L'interaction entre la réaction au niveau de l'industrie face à des changements tarifaires et celle au niveau agrégé est assez complexe. Le recours aux explications traditionnelles de variation dans les dotations factorielles relatives d'une industrie à l'autre n'est pas pertinent en présence d'économies d'échelle et de concurrence imparfaite. Les utilisateurs de GET doivent avoir une connaissance plus grande des relations microéconomiques au niveau de l'industrie que celle qu'exige l'utilisation de modèles traditionnels EGC.

1.3 Les fondements microéconomiques de la détermination des prix, l'entrée et la sortie de firmes

Cette section essaie d'exposer l'analyse microéconomique, au niveau de l'industrie, de la détermination des prix, de l'entrée et de la sortie des firmes dans le cadre du modèle GET. Il faut se rappeler qu'il y a deux catégories d'industries dans le secteur manufacturier, soit les industries dont la majeure partie de la production est en concurrence avec des produits provenant de l'étranger, et les industries dites contestables qui sont largement orientées vers l'exportation et qui n'ont pas un marché national protégé. Une bonne partie des industries exploitant les ressources naturelles entreraient par exemple dans cette dernière catégorie. Une grande partie de l'intérêt que présente GET vient de son aptitude, dans un cadre interindustriel, à prendre en compte une situation de concurrence imparfaite sur des marchés restreints mais protégés.

Le modèle de base qui sous-tend l'hypothèse de détermination des prix en concurrence monopolistique du modèle GET est le modèle de Chamberlin. Ce modèle est illustré au graphique 1.1. En situation d'équilibre, les profits sont nuls et la production de chaque firme est établie de telle sorte que le coût marginal est égal au revenu marginal perçu : ces conditions donnent lieu à la familière condition de tangence entre la courbe de coût moyen et la courbe de demande perçue, dd'. En ajoutant des éléments du commerce international à ce modèle, on a admis implicitement que chaque firme «chamberlienne» est en concurrence avec des firmes étrangères qui produisent des biens qui sont des substituts proches mais imparfaits. En outre, le type de bien produit par la firme nationale peut être commercialisable à l'étranger. L'introduction de la protection des biens domestiques fait effectivement monter les prix des substituts produits à l'étranger pour les consommateurs nationaux; cela déplace la courbe DD' vers la gauche, et partant, la courbe dd' également. Quelle est la réaction du marché national à cette variation de la demande? Il y a, à la fois, entrée de nouvelles firmes nationales et un changement de la position de chaque firme sur la courbe de coûts. Si la courbe de la demande perçue dd' devient plus élastique à la faveur d'une réduction de la protection sur le marché national, la marge bénéficiaire prise sur le coût marginal baissera, et en situation d'équilibre la taille de la firme augmentera. La réduction de la protection se solde donc par un plus petit nombre de firmes, produisant chacune à des coûts moindres et à un niveau plus élevé. Le graphique 1.1 illustre une variation des courbes dd' et DD' où, au nouveau point d'équilibre, la firme produit à un coût moindre et à un niveau plus élevé.



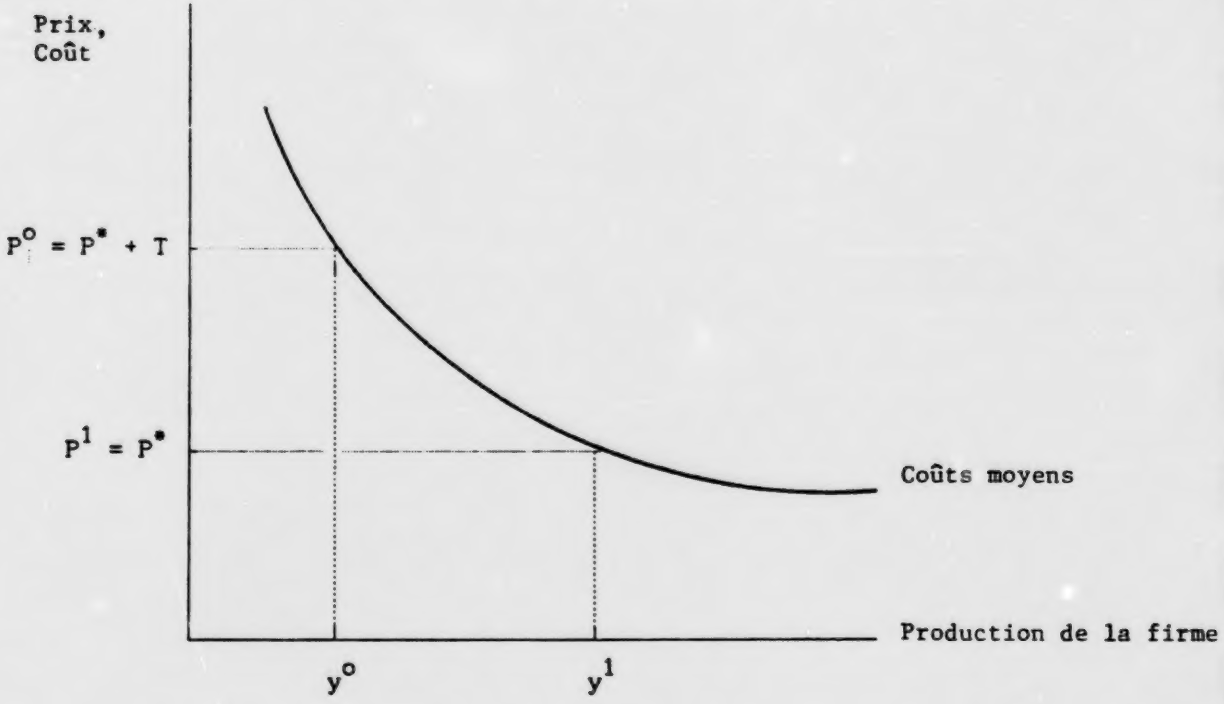
Graphique 1.1

Équilibre en concurrence monopolistique

Une hypothèse alternative de détermination des prix est celle d'Eastman-Stykolt selon laquelle les prix intérieurs sont fixés de façon à correspondre aux prix des industries concurrentes étrangères sur le marché intérieur. L'absence de concurrence effective au niveau des prix sur le marché national est considérée comme le résultat naturel du désir collusoire de l'oligopole d'éviter la concurrence au niveau des prix. Une firme type au sein de l'oligopole est représentée au graphique 1.2, le prix sur le marché national P étant fixé au niveau de prix mondial P*, majoré des droits de douane T. L'entrée dans le marché oligopolistique réduit la production par firme jusqu'à ce que les profits économiques de chacune deviennent nuls. Un baisse des tarifs T à 0 entraîne la baisse des prix des concurrents étrangers à P*. La réponse des firmes nationales est de suivre l'exemple des concurrents étrangers pour essayer de préserver le marché national. Le graphique 1.2 montre que dans le cas de rendements croissants à l'échelle, la production par firme s'accroît de y^0 à y^1, provoquant ainsi une baisse du coût moyen de production. On observe que les établissements de plus large envergure produisent plus efficacement après l'élimination de la protection sur le marché national, mais certaines firmes devront quitter le marché dans la période de transition vers le nouvel équilibre à long terme.

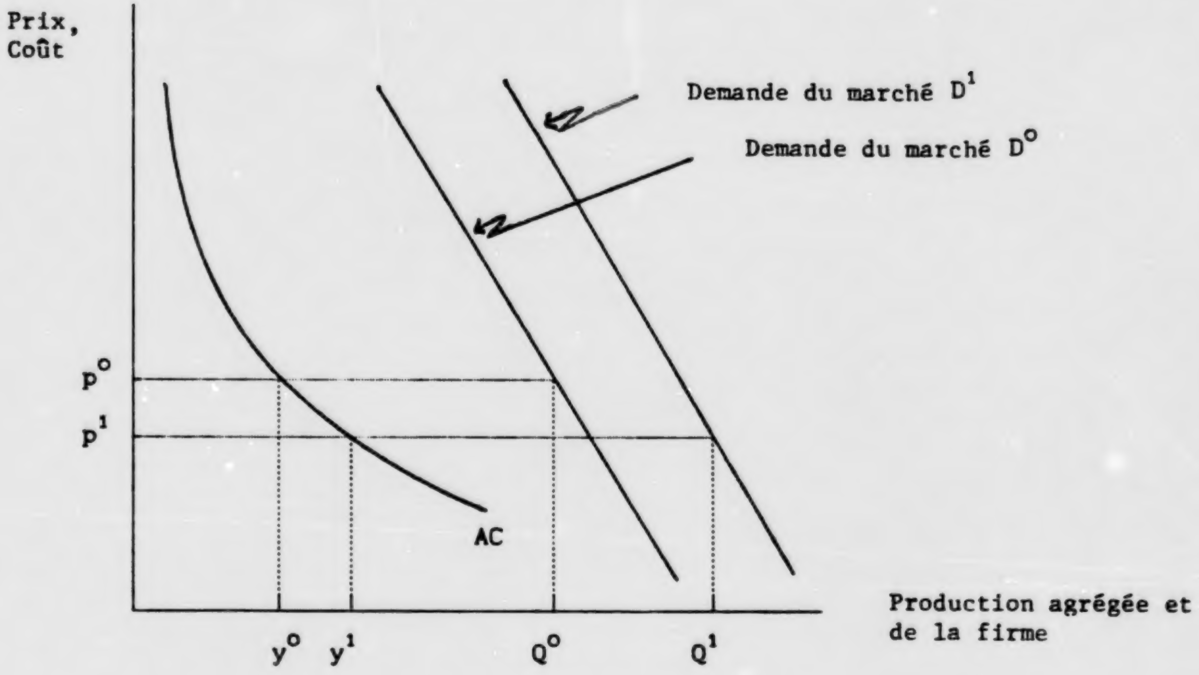
Au sein des industries orientées vers l'exportation, on peut prétendre que la concurrence au niveau des prix est assez importante pour que les prix soient déterminés par les coûts moyens. Cette hypothèse est maintenant connue sous l'appellation de théorie des marchés contestables. La principale implication de cette théorie en matière de politiques des échanges internationaux est que la réponse la plus probable à une variation de la demande est une modification de la taille des firmes et non l'entrée ou la sortie de ces firmes. Le graphique 1.3 montre un équilibre sur un marché contestable avec trois firmes. Chacune des firmes produit initialement sur sa courbe de coût moyen AC au niveau de production y^0 et au prix P^0. Une variation de la courbe de demande sur le marché de D^0 à D^1 se soldera par une répartition uniforme de la croissance de la demande entre les trois firmes; la production de chaque firme passera de y^0 à y^1 et les prix baisseront à P^1 à cause de l'augmentation de l'échelle de production, et partant, de la réduction des coûts de l'industrie. Si les coûts des firmes se situent déjà près du plancher du coût moyen, ou si elles ont déjà atteint un échelle efficace de production, l'augmentation de la demande ne peut pas donner lieu à une baisse sensible des coûts.

La libéralisation des échanges a un certain nombre de voies d'influence dans le cadre du modèle GET. Certains des plus importants effets d'équilibre général ont déjà été examinés dans la section précédente. Les théories de détermination des prix, cependant, forment le coeur microéconomique à la base des variations de productivité qui sont très importantes dans ce modèle. Dans un contexte de libéralisation des échanges bilatéraux, l'élimination des droits de douane nationaux et étrangers se solde par la rationalisation des activités dans les industries dont la production est en concurrence avec les importations, et par l'expansion dans les industries orientées vers l'exportation. Il est possible que, dans un secteur où les échanges intra-industries sont importants, une branche dont les produits sont initialement en concurrence avec les produits importés devienne orientée vers l'exportation à condition qu'elle se spécialise et réduise ses



Graphique 1.2

Détermination des prix selon l'hypothèse Eastman-Stykolt



Graphique 1.3

Détermination des prix sur des marchés contestables coûts. Au niveau de l'équilibre partiel, la libéralisation des échanges provoque en premier lieu une baisse des prix et des coûts moyens de production. L'histoire cependant ne finit pas là.

Un autre processus d'ajustement est le relèvement simultané des prix des facteurs de production, ce qui fait déplacer vers le haut les courbes de coût à mesure que l'échelle d'équilibre des firmes augmente. Le résultat net de ce processus est un niveau de production plus efficient, mais des prix des facteurs plus élevés en termes réels. C'est cet aspect de l'analyse de l'équilibre général qui importe tant afin de déterminer les effets des politiques relatives aux échanges internationaux. On prétend habituellement que les industries dont les produits sont en concurrence avec les importations sont intensives en main-d'oeuvre et, ainsi, qu'une réduction de la protection aura pour effet de baisser la rémunération en termes réels du travail. Cette vision des choses ignore les économies d'échelle. Si la réduction de la protection s'accompagne d'une augmentation de l'échelle de production alors, en situation d'équilibre, la productivité moyenne du travail augmentera de même que les salaires réels. Comme la main-d'oeuvre est le principal facteur rare au sein de l'économie canadienne, en supposant que le capital est mobile à long terme, les gains de productivité résultant de libéralisation des échanges se manifesteront en fin de compte dans une hausse des salaires réels. La baisse des prix à l'exportation par rapport aux prix à l'importation représente une détérioration des termes de l'échange. Étant donné que les tarifs au Canada sont en moyenne plus élevés que ceux des États-Unis, on prétend généralement qu'une réduction bilatérale des tarifs douaniers donnera lieu à une détérioration des termes de l'échange du Canada. Mais cette détérioration calculée en fonction de prix des facteurs constants sera amoindrie dans une certaine mesure par les gains de productivité dans les industries dont les produits sont en concurrence avec les importations, qui relèvent le niveau général des salaires réels dans l'économie. Des salaires élevés tendront à limiter la baisse des prix à l'exportation, réduisant ainsi l'ampleur de la détérioration initiale des termes de l'échange.

En résumé, cette section a donné un bref aperçu des théories de détermination des prix utilisées dans GET et a esquissé les interactions entre ces théories et les caractéristiques d'équilibre général du modèle. Les travaux en cours et à venir sur ce domaine iront probablement dans le sens d'une modification de l'hypothèse d'absence de barrières à l'entrée. Dans de nombreux secteurs, celui de l'assemblage de véhicules automobiles par exemple, qui sont assez importants dans l'économie canadienne, cette hypothèse n'est pas appropriée. Ce qui fait défaut ici c'est une théorie acceptable de la structure et du comportement des marchés qui prenne simultanément en compte les barrières à l'entrée, les décisions de détermination des prix et de la production, mais qui soit suffisamment souple pour être mise en oeuvre dans un modèle EGC.

1.4 La politique des échanges extérieurs dans le modèle GET

L'objectif de cette section est d'examiner les questions de politique en matière d'échanges internationaux pour lesquelles GET peut être utilisé. Différents modèles font différentes choses. Le modèle GET, dans sa forme actuelle, est conçu pour traiter un ensemble spécifique de questions. Dans l'avenir, la construction de modèles sera influencée par le besoin de traiter des questions de politique autres que celles que GET analyse actuellement.

En premier lieu, il importe de souligner que, étant donné qu'il s'agit d'un modèle statique d'équilibre général calculable orienté vers les questions d'allocation des ressources, GET n'est pas conçu comme un outil de prévision. Son objectif principal est de simuler des choix en matière de politique économique en partant d'un ensemble d'hypothèses hautement structurées. Prenons par exemple la question du coût de la protection pour l'économie canadienne. En comparant les résultats de la résolution du modèle pour les premières années de 1980 avec et sans tarifs douaniers canadiens, nous répondons à la question de politique «contrefactuelle» suivante : «quelle aurait été la physionomie de l'économie canadienne au début des années 1980 si la seule différence structurelle au sein de l'économie avait été l'absence de droits de douane»? Par contre, le modèle ne répond pas à la question suivante : «si les tarifs sont graduellement éliminés entre 1989 et 1999, quelle sera la physionomie de l'économie»? Manifestement, pour l'analyse de politiques, la dernière question est la plus intéressante, mais ce n'est pas un question qu'un modèle de simulation tel que GET peut traiter. Qu'importe, les réponses données dans une analyse «contrefactuelle» de politiques contiennent de bonnes indications quant aux changements futurs des politiques, et c'est ce qui explique la grande importance qu'on attache à une mise en oeuvre empirique soignée de modèle. On peut, en soumettant les paramètres du modèle à une analyse de sensibilité, relever ceux qui revêtent une importance particulière. On a ainsi une idée des domaines dans lesquels il faudrait mener des recherches lorsqu'il s'agit d'évaluer les répercussions probables des changements futurs des politiques. Les modèles EGC s'avèrent des outils d'analyse quantitative pertinents lorsqu'ils sont utilisés adéquatement.

Le modèle GET est conçu pour l'analyse des effets à long terme du commerce international et de la concurrence sur la structure industrielle au sein de l'économie canadienne. En modélisant le flux des échanges entre le Canada, les États-Unis et le Reste du monde, on peut répondre à une foule de questions. Certaines de ces questions sont énumérées ci-après sans souci particulier quant à leur importance relative.

Sauf indication contraire, toutes les références portent sur une variable nationale (canadienne). Le flux des échanges et les termes de l'échange sont les seules variables endogènes non canadiennes dans le modèle GET.

1. Les effets des variations des termes de l'échange avec n'importe laquelle des trois régions sur les prix à la production, les prix des facteurs de production, la production industrielle, l'emploi et le stock de capital.

2. Les effets sur les prix, la production, l'échelle de production et la productivité des industries des changements de la structure de protection au Canada, aux États-Unis ou dans le RDM, y compris l'augmentation des mesures de protection ou la signature d'accords commerciaux régionaux comme le libre-échange entre le Canada et les États-Unis.

3. Les effets sur le flux des échanges, le revenu réel, les salaires et la valeur ajoutée par industrie des changements de degré de protection dans n'importe laquelle des trois régions.

4. Les répercussions de politiques industrielles sous la forme de subventions en capital ou en main-d'oeuvre, de subventions à la production, de subventions à l'exportation, de restrictions à l'entrée, ou de protection contre les importations dans des secteurs spécifiques. Ces répercussions peuvent être évaluées à la fois au niveau de l'industrie et au niveau de l'ensemble de l'économie.

5. Les chocs technologiques peuvent être évalués en fonction de leurs répercussions sur l'industrie et sur des variables agrégées. À titre d'exemple, un accroissement de productivité dans un secteur particulier aura des répercussions indirectes sur tous les autres secteurs. GET est conçu pour traiter ce genre de questions. La caractéristique particulière de GET est sa capacité à prendre en compte l'innovation technologique qui modifie la taille optimale de production d'une usine dans une branche donnée d'activité.

6. Les variations des composantes de la demande nationale ou étrangère peuvent être évaluées. À titre d'exemple, on peut évaluer les répercussions sur les industries ou sur l'ensemble de l'économie de la croissance d'un bien donné sur les marchés d'exportation non américains.

7. La version à court termes de GET, qui est essentiellement un modèle de détermination de la demande avec des salaires rigides et du chômage, est présentée au chapitre 4. Ce modèle a une utilité limitée comme outil d'analyse des répercussions de la plupart des questions énumérées aux points 1 à 6 ci-dessus, à l'exception des questions portant sur la structure industrielle ou sur l'efficacité à long terme. Le modèle est conçu pour établir les répercussions d'un choc sur un horizon de un à deux ans. Partant de l'hypothèse de la rigidité des salaires et de capacités excédentaires dans l'économie, le modèle donne des estimations des effets du choc sur l'emploi par industrie, et sur la balance commerciale. Le modèle est limité en ce sens qu'il ne peut pas actuellement prendre en compte les industries ayant des contraintes d'offre.

Ce dernier point met fin à la liste des questions auxquelles le modèle est apte à répondre. Si on s'en tient aux normes des modèles d'analyse actuellement en utilisation, GET est assez souple et peut être modifié pour prendre en compte une foule de questions liées aux politiques microéconomiques. À l'étape actuelle, il faut des données additionnelles dans le but de traiter un grand nombre de questions d'ordre fiscal. Les travaux en cours sur la structure et les données du modèle vont dans cette voie.[1]

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[1] Il faut également remarquer que GET n'est pas un modèle qui peut répondre directement aux questions régionales de l'économie canadienne. Il serait utile de disposer d'un modèle régional pour évaluer plusieurs de ces questions. Bien qu'il soit techniquement réalisable de construire une version régionale du modèle GET, les contraintes en matière de données imposeraient une structure industrielle plus agrégée. De plus, la construction d'un tel modèle exigerait des ressources considérables.

Chapter 1

An Introduction to the GET Guide

1.1 Introduction

This manual is written for the purpose of explaining the structure and coding of the general equilibrium trade model, denoted by the acronym GET, which is used in the Department of Finance for policy analysis. The model was originally designed for the purpose of analyzing the Canada-U.S. negotiations on a bilateral 'free trade' area, but has uses beyond that original intention. The model falls in the category of a 'general equilibrium model' as the term has become popularized in the 1980's. It is a large scale numerical model which focuses on the role of relative price adjustment in factor and commodity markets as the principal means of economic adjustment, together with changes in industrial structure. Computable General Equilibrium Models, or CGE's, have a distinguishing feature that the theoretical underpinnings of the model in terms of assumptions on tastes, technology, resources, and government polices are usually quite explicit. Unlike many macroeconomic models, CGE models do not start with reduced form supply and demand or equilibrium conditions; these are all derived from more primitive microeconomic assumptions. The GET model falls squarely in this class of models.

The manual is written for two groups of readers. Those who will need a manual and are currently working on the model, or involved in making structural changes to the model, as well as for those who are interested in understanding how the model works, and the basic workings of the programs which implement the model. Different readers will find different parts of the manual more interesting than others. The details of the theoretical structure are laid out in chapters 2 and 4. Readers concerned with actual use of the programs implementing the models will want to read in addition chapters 5 and 6. Chapter 3 concerns details of model output, and may be of interest to those using the output of the model, but are not particularly interested in the nuts and bolts of the empirical procedures and computational aspects of model solving. Appendix A.1 describes the construction of the basic product and income flows from input-output tables consistent with the aggregative/theoretical structure of the model. This appendix will be of interest to those involved in the detail of model calibration, either on future versions of GET, or models like it.

Comprehension of much of this manual presumes a fair degree of sophistication with economic models, and economic accounting procedures. The theory underlying the model relies on traditional 'real' trade theory, and in addition some of the newer 'imperfect competition and international trade' literature as summarized for example by Helpman and Krugman (1985). Readers attempting to work through the chapter on calibration, chapter 5 should have a working familiarity with calibration procedures in applied general equilibrium. Shoven and Whalley (1984) and Whalley (1985) provide good discussions of these procedures.

Those who are going to be working in detail with the model should keep a copy of the fortran code for both the solution algorithm, PILOT, and the calibration program, TEST, at hand when working through the relevant chapters. Proficiency in applied general equilibrium analysis calls for the ability to go back and forth readily between mathematical equations embodying the relevant economic theory, and the fortran code which implements that theory in practice. This proficiency usually only comes with considerable experience.

The only remaining purpose of this chapter is to provide for the non-technical reader a description of the GET model, its main features and what makes it unique in this class of models. Sections 1.2 and 1.3 provide an introduction to the model in non-technical terms. Section 1.4 discusses CGE models as tools for policy analysis and some of the questions the GET model is designed to address.

1.2 A Summary of the General Equilibrium Characteristics of GET

In this section a brief description of the general equilibrium simulation model GET is provided. More detailed descriptions of the original GET can be found in Harris (1984b) and current version is detailed in chapter 2. In the interests of brevity, the discussion will focus on those aspects of the model which are relatively novel.

All the general equilibrium aspects of the model are quite conventional. The model is less than a 'full' general equilibrium model, since the foreign sectors, both U.S. and Rest-of-World (ROW), are summarized by exogenous import prices and a set of export demand equations; the emphasis is on equilibrium within the Canadian economy. Factor markets are competitive, as are all product markets in the non-manufacturing sectors. Prices are flexible and full employment is assumed to be an adequate description of long-run equilibrium. On the consumption side, domestic demands are generated by a single aggregate consumer maximizing a utility function subject to a budget constraint. The utility aggregator across commodity classes is Cobb-Douglas. Within each commodity class the Armington assumption is maintained; U.S., ROW, and domestic goods are imperfect substitutes as given by a CES aggregator over these three commodity groups.

Export demand in the ROW and U.S. is generated by a consumer for each region with exogenous income who views home goods, Canadian goods, and all other goods as imperfect substitutes. In the case of the U.S. import demand equations this specification allows one to quantify the extent of trade diversion and trade creation. Bilateral tariff reduction between Canada and the United States at constant prices will shift U.S. imports towards Canadian goods. In the model Canada is presumed to be a price maker in its export markets but a price taker in its import markets.

The assumption that the country sets prices in its export markets but is a price taker in its import markets is problematic. While it is consistent with some of the evidence for Canada (see Appelbaum and Kohli, 1979), there is an obvious logical problem. Suppose the world widget industry is imperfectly competitive. Domestic firms can set prices, but within the model the actions of these firms do not affect the prices set by foreign competing firms, either U.S. or ROW. The major defense for this hypothesis is that domestic firms face a large world industry supplying a close but imperfect substitute. Under the assumption that the total share of the world widget market held by domestic firms is small, the response of the world industry against price changes by the domestic firms is taken as being sufficiently small to ignore.

On the production side firms employ capital, labour, and intermediate goods to produce the industry output. Foreign and domestic intermediate inputs are regarded as imperfect substitutes. On the output side each firm produces one product, and in only one industry.

The manufacturing sector contains those industries that are potentially non-competitive. The regulated industries are not explicitly modelled as non-competitive. Each non-competitive industry is made up of an endogenous number of representative firms; each firm has the same technology. The technology is characterized by a fixed cost; a fixed bundle of capital and labour is required to set up a firm. Long-run average variable costs are independent of output, being a function solely of input prices and technology parameters. Average cost is thus declining everywhere, asymptotic to unit variable costs. With increasing returns to scale in production the efficiency of resource use is affected by the scale of individual firm output. GET explicitly models the determination of firm scale, as well as entry and exit of firms in the non-competitive industries. Within the competitive industries there are no fixed costs and a conventional constant returns specification is used. Functional forms, though not parameter values, are the same as those used to describe variable cost in the non-competitive sectors.

Labour is homogeneous and mobile between industries. Capital services are homogeneous and mobile between industries and between countries. Furthermore, capital services are assumed to be in infinitely elastic supply at the world rental rate. Labour is supplied inelastically by domestic consumers. Domestic income derives from labour services, capital services from the capital endowment of domestic consumers, and net government transfers. Given that capital is mobile, balance of payments equilibrium is a current account balance concept: surplus on trade account must equal rental payments on foreign-owned capital.

The manufacturing industries are divided into two groups, import competing and export oriented. In the export oriented industries there exist scale economies, but the domestic firms are presumed to compete in a highly competitive world market. The market structure of this world industry is described by the contestable market theory of Baumol, et al. (1982).

The equilibrium concept employed in the import competing imperfectly competitive industries is a modified Cournot-Chamberlin type of equilibrium at the industry level. Two hypotheses are employed in describing the pricing behavior of firms. One is a type of monopolistic competition pricing hypothesis (MCH) with perceived demand curves. The Lerner rule is used to set prices conditional on an elasticity of perceived demand curve. The perceived demand elasticity is constructed by having each firm conduct a hypothetical comparative statics experiment changing its price and observing the demand response under the assumption that industry demand is evenly shared by all domestic firms. The firm's perceived demand elasticity is thus related to the underlying parameters of technology, preferences and export demand. Changes in this elasticity will change the mark-up of price over marginal cost.

The other pricing hypothesis is motivated by the Eastman-Stykolt (1967) model of protected oligopolies in small open economies. The basic idea is that the domestic firms set their prices around the collusive focal point provided by the world price plus domestic tariff on the foreign competing good. In the model of this paper it is assumed that the U.S. industry is the principal competitor with the Canadian industry. Reduction in Canadian tariffs against U.S. imports provides a direct mechanism by which domestic prices are cut in response to trade liberalization between Canada and the United States. The pricing rule used in GET is a mixture of the MCH and ESH, with an exogenous weight attached to each. It is obvious that this approach to pricing is somewhat ad hoc, but it has the virtue of being empirically tractable. Freedom of entry and exit is assumed in the non-competitive industries. All entry barriers other than fixed costs are ignored. A long-run equilibrium is characterized by zero economic profits in all industries, and price equal average cost.

At the general equilibrium level, the productivity shifts due to changes in scale efficiency show up in prices and wages. At the aggregate level changes in real income, the volume and terms of trade, and the real wage are the most important responses to trade liberalization. The interaction between the industry level response to tariff changes and the aggregate response is quite complex. Traditional explanations in terms of relative factor intensities across industries are inadequate in the presence of scale economies and imperfect competition. A deeper understanding of the microeconomics at the industry level is necessary for users of GET than is required in traditional competitive CGE models.

1.3 The Microeconomics of Pricing, Exit and Entry in GET

This section attempts to flesh out the microeconomic analysis at the industry level of what is going on in the GET model with respect to pricing and exit and entry. Recall that there are two classes of industries within the manufacturing sectors, the import-competing manufacturing industries who face competition along a majority of product lines from foreign competition, and the 'contestable' export industries that are largely export oriented, and are not faced with a protected domestic market. Many of the natural resource processing industries would fall in this category for example. Much of the interest in GET stems from its ability, within an interindusty framework, to account for the imperfectly competitive nature of the market structure in a small but protected market environment.

The basic model which motivates the Monopolistic pricing hypothesis of the GET model is the Chamberlin model of monopolistic competition. The familiar equilibrium of this model is depicted in figure 1.1. In equilibrium each firm earns zero profits and output is set such that marginal cost equals perceived marginal revenue; these conditions give rise to the familiar tangency condition between the average cost curve and perceived demand curve dd'. Adding international trade to this model now implicitly recognized that each Chamberlinian firm competes with foreign firms producing goods which are close but not perfect substitutes. In addition the variety produced by the Home firm may have a market abroad. Introducing protection for the Home market effectively raises the prices of foreign produced substitutes to Home consumers; this cause the DD' curve to shift to the left and hence also the dd' curve. What is the response to this shift in demand? One response to the increase in the domestic market is the entry of new domestic firms; the other response is the ultimate change in the position of each firm on the cost curve. If the perceived demand curve dd' becomes more elastic with a reduction in protection to the Home market, then the markup of price over marginal cost will fall, and in equilibrium the size of the firm will increase. Thus reduced protection leads to fewer firms each producing at lower cost and higher output. In figure 1.1 a shift in the dd' and DD' curve is indicated such that at the new equilibrium the firm is producing at lower cost and higher output.

An alternative pricing hypothesis is the Eastman-Stykolt hypothesis which argues that domestic prices are set to match the foreign competing price. This lack of effective price competition in the domestic market is viewed as the natural outcome of a collusive oligopoly's desire to avoid price competition. A typical firm in the oligopoly is depicted in figure 1.2 with the price in the domestic market, P, set at the world price, P^*, plus tariff T. Entry into the oligopolistic market reduces output per firm until each firm just earns zero economic profits. A cut in the tariff T to 0 lowers the foreign competing price to P^*. The domestic pricing response to this is to follow suit attempting to preserve the home market. In figure 2 we see that under increasing returns to scale the output per firm increases form $y_0$to y_1, giving rise to a decrease in average cost of production. Thus larger scale plants are observed producing more efficiently after the cut in domestic protection, but exit will be required by some firms in the transition to the new long run equilibrium.

In export oriented industries it can be argued that price competition in these industries is sufficiently great that prices are necessarily driven to average cost. This hypothesis is now come to be known as the 'Contestable Markets Theory'; its major implication in the context of trade policy is that a change in the scale of individual firms is the most likely response to a shift in demand rather than the entry or exit of firms. Thus in figure 1.3 we depict a 3-firm contestable market equilibrium. Initially each firm is producing on its average cost curve AC at output y^o and price P^o. A shift in the market demand curve from D^o to D^1 will result in all three firms sharing in the increase in demand evenly, with individual firm output rising from y^o to y^1, and price falling to P^1 as a result of the increased scale and hence reduced cost in this industry. If the firms are already near the bottom of the average cost, or have already realized efficient scale then the increase in demand may not result in much of a decrease in cost.

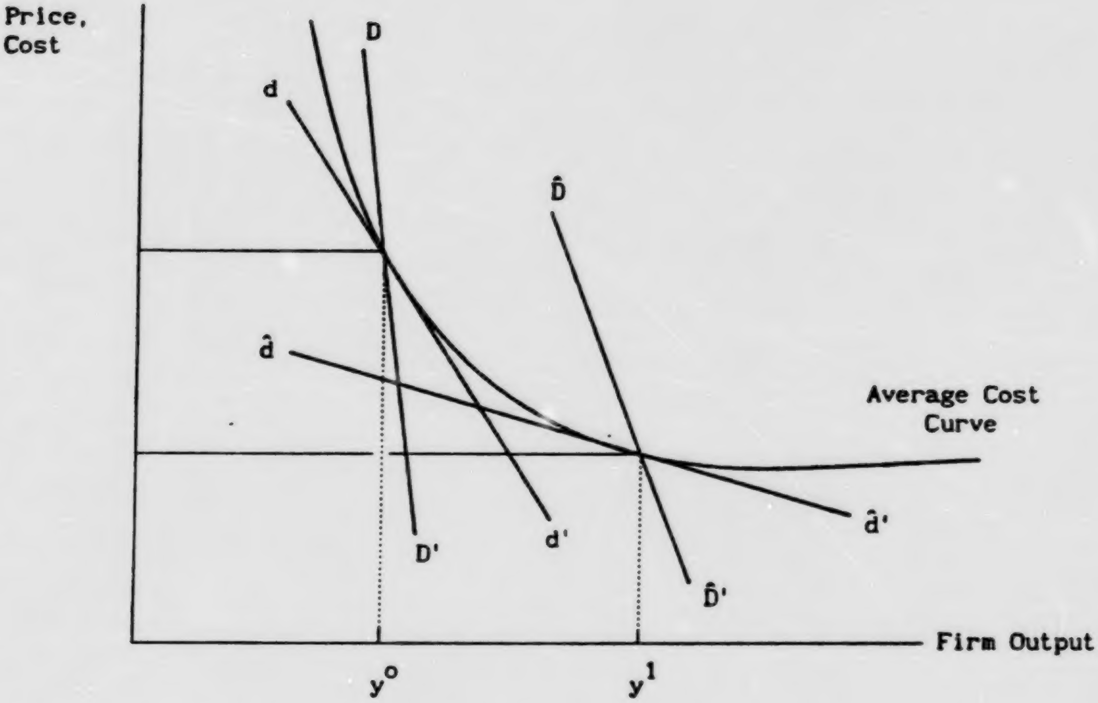

Figure 1.1

Equilibrium with Monopolistic Competition

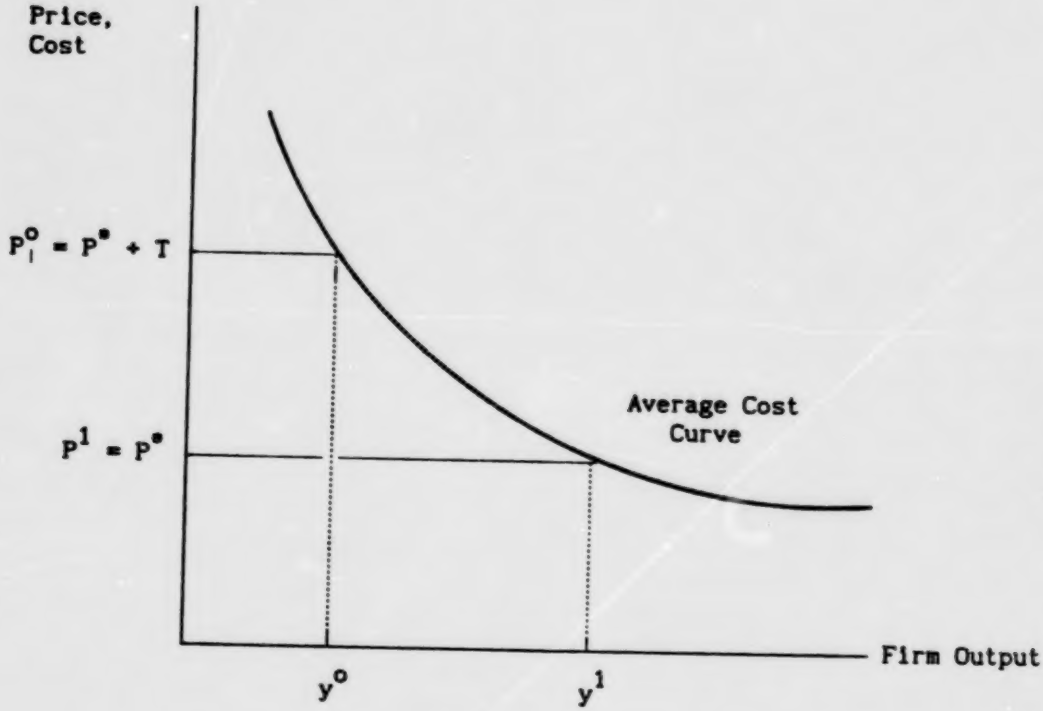

Figure 1.2

Eastman-Stykolt Pricing

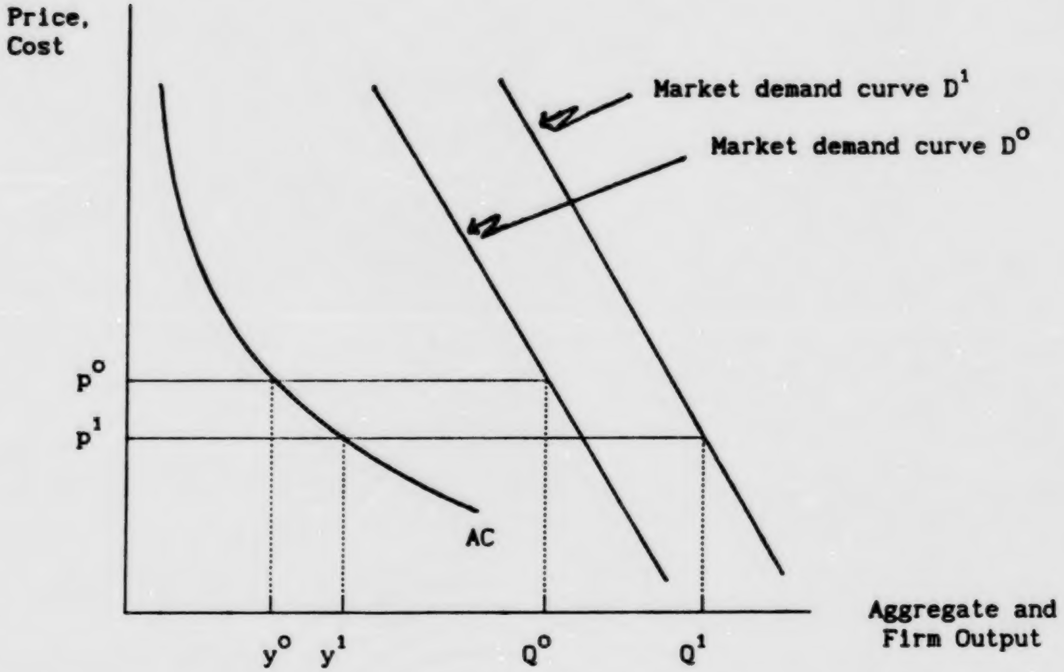
Price, Cost
Market demand curve D^1
Market demand curve D^0
p^0
p^1
AC
y^0
y^1
Q^0
Q^1
Aggregate and Firm Output

Figure 1.3

Contestable Market Pricing

Trade liberalization has a number of channels of influence within the GET model. Some of the more important general equilibrium effects have already been discussed in the previous section. The pricing theories however form the microeconomic core of the basis for the productivity shifts which are so significant in the GET model. Under a bilateral trade liberalization the domestic and foreign tariff cuts result in rationalization within import competing industries, and expansion in export industries. It is possible in an industry with a significant amount of two-way or intra-industry trade, that an industry which is initially import-competing may actually become export oriented, as it specializes and reduces costs. At the partial equilibrium level the trade liberalization first causes a reduction in prices and decreased average costs of production. That however is not the end of the story.

An alternative adjustment process is for a simultaneous increase in factor prices, shifting cost curves up, while firms' equilibrium scale rises. The net result is a more efficient level of production, but higher real factor prices. This is the aspect of general equilibrium analysis which is so important for the purposes of tracing out the effects of trade policy. The usual story is that import competing industries are labour intensive, and thus a cut in protection will lower the real wages of labour. This story ignores the role of scale economies. If reduction in protection is accompanied by an increase in scale, then the average productivity of labour rises, and thus real wages in equilibrium will rise. As labour is the major scarce factor in the Canadian economy, assuming capital is mobile in the long run, the productivity gains from the trade liberalization will manifest themselves ultimately in higher real wages. Reductions in the price of exports relative to imports is a deterioration in the terms of trade. Because Canada has a tariff structure which is on average higher than that of the U.S. it is commonly argued that a bilateral tariff cut will result in a deterioration in the terms of trade to Canada. But the terms of trade loss calculated at constant factor prices will be mitigated to some extent by the productivity increases in import competing industries which raise the general level of real wages in the economy. Increased wages will tend to keep export prices from falling as much as they otherwise would, thus reducing the initial terms of trade loss.

In summary this section has given a brief sketch of the pricing theories used within the GET model and suggested how they interact with the general equilibrium characteristics of the model. Current and future research in this area will probably go in the direction of relaxing the free entry assumption. In a number of sectors, for example auto assembly, which are quite important in the Canadian economy, this is not an appropriate assumption. The major stumbling block at this point in time is an acceptable theory of market structure and conduct, which simultaneously accounts for entry barriers, pricing and output decisions, but is sufficiently tractable that it can be implemented within a CGE model.

1.4 Policy in the GET Model

The purpose of this section is to discuss the type of trade policy issues which the GET model is designed to handle. Different models do different things. The GET model is designed to handle a specific set of issues in its current implementation. Future model development will be influenced by the need to address different policy issues than those GET is currently designed to handle.

First it is important to emphasize, that as a static computable general equilibrium model concerned with resource allocation issues, GET is not designed as a forecasting tool. Its principal purpose is to ask 'what if' questions about economic policy under a set of highly structured assumptions. Consider for example the question of the cost of protection on the Canadian economy. By comparing the model solution for the early 1980's period with and without the Canadian tariff we give an answer to the *counterfactual policy question* "what would the Canadian economy have looked like in the early 1980's if the only structural difference in the economy was that the tariffs had not been in place?" The model does not produce answers to the question "if tariffs are removed in stages over the period 1989 to 1999 what will the economy look like in 1999?" Obviously for policy analysis the latter question is the most interesting, but it is not the question a simulation model such as GET can give. Nevertheless the answers given in a counterfactual analysis of policy contain great insights regarding future policy changes, and this is the reason much attention is paid to careful empirical implementation of the model. By undertaking sensitivity analysis on the parameters on the model, it can be discerned which parameters are of particular importance. This in turn suggests where research is needed when evaluating the likely impact of future policy changes. CGE models are a useful quantitative tool to the policy analyst if used properly.

The GET model is designed for the analysis of the long run effect of international trade and competition on the structure of industry within the Canadian economy. By modelling trade between Canada, the U.S. and ROW a variety of questions can be addressed. Some of these are listed in no particular order of importance. Unless indicated otherwise all references are to the domestic (Canadian) variable. Trade flows and terms-of-trade are the only non-Canada endogenous variables appearing in the GET model.

1. The effect on output prices, factor prices, industry outputs, employment, and capital stocks of changes in the external terms of trade between any of the three regions.

2. The effect on industry price, output, scale and productivity of changes in the structure of protection in either Canada, the U.S. or the ROW, including increases in protection, or the formation of regional trading arrangements such as the Canada-U.S. free trade area.

3. The effect on trade flows, real income, wages and value added by industry of changes in the degree of protection in any of the the three regions.

4. The impact of industrial polices in the form of capital or labour subsidies, production subsidies, export subsidies, entry restrictions, or sector specific protection from imports. Detail can be provided on both the industry level effect, as well as the economy wide effect.

5. Technological shocks can be assessed in terms of their impact on industry and aggregate variables. For example an increase in the productivity of a particular sector will impact on all other sectors in a

fairly complicated way. GET is designed to handle this type of question. Particularly unique to GET is the ability to handle technological innovation which changes the efficient scale plant size in an industry.

6. Shifts in the composition of domestic or foreign demand can be assessed. For example a growth in non-U.S. export markets of a particular commodity can be examined for its impact on industry and economy wide variables.

7. The short run version of GET, which is essentially a demand determined model with rigid wages and unemployment is outlined in chapter 4. This model has limited use as a tool for impact analysis for most of the questions raised in 1-6 above, with the exception of questions pertaining to long run industrial structure or efficiency. The model is designed to give answers to the impact effect of a shock to the model over a one to two year horizon. Under the assumption of wage rigidity and excess capacity the model gives estimates of the effect on employment by industry, and on the trade balance. The model is limited in that it cannot currently deal with industries with binding supply constraints.

This completes the list of questions which the model is designed to address. By the standards of current policy models in use, GET is quite flexible and capable of being structured to address a wide variety of policy questions concerned with microeconomic policy. At the current stage additional detail is necessary for the purpose of addressing many tax policy questions. Current work on model structure and data is proceeding in that direction.[1]

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[1] It should also be noted that GET is not a regional model. For many Canadian policy issues having a regional model would be useful. Although it is technically feasible to develop a regional version of the GET model, data limitations would mean less industrial detail could be presented. Developing a regional model would also require considerable resources.

CHAPTER 2

G.E.T. Model Structure: Long-Run Equilibrium Analysis

2.1 Introduction

GET is a policy simulation model designed for the express purpose of analyzing the long run impact of economic policy changes at the microeconomic level. It is a Computable General Equilibrium model (a CGE model) which relies on a concept of equilibrium emphasizing the role of relative prices in both factor and product markets as a means of bringing supply and demand into equality. It has a particular emphasis on international trade in a smaller industrial economy, and is concerned with detail of industrial structure.

The general equilibrium aspects of the model are all conventional. Some of these broad G.E. features of the model are as follows.

(i) The model is less than 'full' general equilibrium model as the rest-of-world (R.O.W.) and the U.S. is summarized by exogenous import prices and a set of export demand equations; the emphasis is on equilibrium within the small open economy.

(ii) Factor markets are competitive, as are all product markets in the non-manufacturing sectors. Prices are flexible and consequently full employment is assumed to hold.[2]

(iii) Labour is homogeneous and mobile between industries.

(iv) Capital services are homogeneous and mobile between industries and between countries. Furthermore, capital services are assumed to be in infinitely elastic supply at the world rental rate.

(v) Labour is supplied inelastically by domestic consumers. Domestic income derives from labour and capital services reflecting the endowment of domestic consumers, and net government transfers.

(vi) Given that capital is mobile, balance of payments equilibrium is a current account balance concept; surplus on trade account must equal rental payments to foreign-owned capital.

(vii) The model is static with no explicit treatment of savings and investment.

In assessing the relevance of a general equilibrium model such as GET, the question often arises as to how long the 'long run' is. There is no precise answer to this, but it must clearly be a period sufficiently long that prices are allowed to adjust to correct any imbalances between demand and supply. Furthermore as economic profits are assumed to be zero, or equality of rates of return on capital in all sectors is assumed to hold it must also be a period sufficiently long that adjustments in the capital stock are possible.

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[2] The 'Keynesian short run' version of GET assumes labour markets do not clear, and thus equilibrium is characterized by unemployment. This version of the model will be taken up in Chapter 4.

The details of the model structure are often the important determinants of model results, even comparing models with similar 'broad' features. For those who wish to either use or fully understand the results generated by GET it is important to have a firm grasp of these details. This chapter is intended to provide an explanation of that detail. Before going into the formal equations of the model it may be useful to go over the essential characteristics of different model components.

2.1.1 Commodity and Regional Structure

Within the model there are three economic 'regions', Canada, the United States, and all other countries aggregated into Rest-of-World (henceforth referred to as ROW). Much of the detail of the model is concerned with Canadian (also referred to as the 'domestic region') consumption and production, but trade in both goods and capital services takes place between Canada and the other regions. A principal distinguishing feature of the model is the assumption that each type of commodity, meaning its physical type and quality, is distinguished by the region in which it is produced. Thus shoes produced in Canada are treated differently in both supply and demand than shoes produced in the United States or ROW. In general commodities of the same physical type, but produced in different regions, are thought of as close but imperfect substitutes for each other in final and intermediate consumption. By definition, it only possible to produce 'Canadian' shoes in Canada, and not 'U.S. shoes' or 'ROW shoes'. This assumption has become known in the trade literature as the 'Armington' aggregation assumption and has been used widely in the applied trade literature.[3] It is an assumption which has its own problems[4] but is nevertheless an extremely useful organizing assumption, and at the level of aggregation used in most applied economic models provides an analytically tractable way of accounting for two-way trade between two regions in the same commodity category, or *intra-industry* trade.

In terms of the regional structure, the Canada region is thought of as small relative to both U.S. and ROW. Thus import supply prices in Canada are treated as exogenous to the model. Nevertheless, because Canadian goods are distinct from U.S. and R.O.W. goods, the prices of Canadian supplied goods are influenced by supply and demand conditions within the Canada region. Thus because export prices are endogenously determined, but import prices are exogenously determined, the terms of trade within Canada are endogenously determined within GET, and affected by changes in domestic policy instruments. This particular conjunction of assumptions on export and import prices is, following Harris (1984a), referred to as the 'almost small open economy' (ASOE) assumption.

The assumption that the country sets prices in its export markets, but is a price taker in its import markets is problematic. While this is consistent with some of the evidence for Canada[5] there is an obvious logical problem. Think of the world widget industry as being potentially imperfectly competitive. Domestic firms can set prices, but within the model actions of these firms do not affect the prices set by foreign competing firms. The major defense for this hypothesis is that domestic firms face a large world industry supplying a close but imperfect substitute. Under the assumption that the total share of the world market held by domestic firms is small, the response of the world industry against price changes by the Canadian firms is assumed to be sufficiently small to ignore.

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[3] See Armington (1969).

[4] See Harris (1986b) for a critical review of the Armington assumption.

2.1.2 Demands

On the consumption side domestic final demands are generated by a single consumer maximizing a utility function subject to a budget constraint. The utility aggregator across commodity classes is Cobb-Douglas. Within each commodity class the Armington assumption is maintained; US, ROW and domestic goods are imperfect substitutes which are inputs to a Constant Elasticity of Substitution or CES aggregator over the three commodities.

Export demands are generated by ROW and U.S. consumers with exogenous income who view home goods and all other goods as imperfect substitutes. Furthermore total expenditure on each commodity category is exogenous for each of the two foreign consumers. This specification admits a distinction, in a less than full world general equilibrium model, between price and tariff elasticities of export demand for an 'almost' small open economy.

The final source of commodity demand is intermediate input use, with domestically produced and imported intermediates treated as imperfect substitutes within the domestic production structure. There is one commodity class, non-competing imports, which is both a final and intermediate good, but does not compete with a domestic substitute.

2.1.3 Production Structure

The technology of production requires that firms employ capital, labour and intermediate inputs to produce industry output. Foreign, U.S. and ROW intermediate inputs are regarded as imperfect substitutes. On the output side each firm produces one homogeneous product, and only in one industry.

The manufacturing sector contains those industries which are potentially non-competitive,[6] having some degree of increasing returns to scale in the firm's production function.[7] Each non-competitive industry is made up of an endogenous number of representative firms; each firm has the same technology. The technology of the representative firm in the non-competitive sector is characterized by a fixed bundle of capital and labour required to set up a an 'active' firm producing positive output. As each firm requires a minimum amount of capital and labour to operate the technology is said to be characterized by an indivisibility and the presence of *fixed costs*. These are recurring costs which are independent of the level of firm output and are not avoidable, even in the long run. This type of fixed cost is to be distinguished from the Marshallian notion of short-run fixed costs which arise from quasi-fixed factors, but are avoidable in the long run. Long run average variable costs of production are *independent* of output, being a function solely of input prices and technology parameters. Average cost is thus declining everywhere, asymptotic to unit variable costs. Unit variable costs are equal to marginal cost. The extent of unexploited scale economies is conventionally measured by the cost elasticity defined as the ratio of marginal to average cost, a number less than unity.

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[5] See Appelbaum and Kohli (1979).

[6] The regulated industries are not explicitly modelled as non-competitive.

[7] The individual firm's production function thus exhibits economies of scale which are defined to be *internal* to the firms. *External* economies are often used in trade models as a characteristic of *industry* cost structure. Helpman (1984) examines in detail the difference between the two types of scale economies in trade models.

Within the competitive industries there are no indivisibilities and a conventional constant returns to scale (CRS) specification is used. Functional forms for cost functions in CRS industries, although not parameter values, are the same as used to describe variable cost in the non-competitive sectors.

2.1.4 Industrial Organization and Pricing

The model has some features in common with the recent theoretical analysis of trade and imperfect competition (Helpman and Krugman, 1985). The equilibrium concept employed in the imperfectly competitive industries is a modified Cournot-Chamberlin type of equilibrium at the industry level. Firms within each industry produce a homogeneous good which competes with an imperfect foreign substitute. Two hypotheses are employed in describing pricing behaviour of import competing firms. One is a type of monopolistic competition approach with perceived demand curves. The Lerner rule[8] is used to set prices conditional on an elasticity of a perceived demand curve. The perceived demand elasticity is constructed by having each firm conduct a hypothetical comparative statics experiment by changing its price and observing the demand response under the assumption that industry demand is evenly shared by all domestic firms. The firm's perceived demand elasticity is thus related to the underlying parameters of technology, preferences and export demand. Changes in this elasticity will change the markup of price over marginal cost. This particular hypothesis on industry pricing will be referred to as the monopolistic competition hypothesis (MCH); strictly

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[8] The Lerner rule says that, given a perceived price elasticity of demand η, a profit maximizing firm will set price P, in relation to marginal cost, MC, such that

$$\left(\frac{P-MC}{P}\right) = \frac{1}{|\eta|} .$$

For this rule to be logically consistent with profit maximization it is necessary that $|\eta| > 1.0$.

speaking, given the output sharing rule used, this pricing rule is not the same as Cournot-Chamberlin pricing. MCH implies a higher markup than would be used in a Cournot quantity-setting industry equilibrium.

The alternative pricing hypothesis is motivated by the Eastman-Stykolt model of protected oligopolies in small open economies (Eastman and Stykolt, 1967). The basic idea is that the domestic firms set their prices around the collusive focal point provided by the world price plus domestic tariff of the foreign competing good. Reduction in domestic tariffs provides a direct mechanism by which domestic prices are cut. The Eastman-Stykolt Hypothesis (ESH) has been given considerable support in studies of Canadian industrial organization.[9]

In those industries which are heavily export oriented the pricing rule is a version of the contestable markets theory as described in Helpman and Krugman (1985), chapter 4. Firms set price at average cost, and the number of firms is exogenous to shifts in cost and demand contemplated within the model. This theory of industry conduct is rationalized by the assumption that these firms are competing in a large external market, and in the absence of domestic entry barriers the industry is scale efficient relative to demand. In the presence of scale economies the industry will benefit or lose with increases or decreases in the external demand for their product. In addition in some cases it is assumed that firms price discriminate between home and foreign markets. This distinction opens up the important empirical question of how a reduction in foreign trade barriers impacts on the volume of export sales versus the price received by home producers in the export market.

The pricing rule used in the model simulations is a mixture of the MCH, EHS, and contestable market pricing. Sensitivity analysis on various pricing assumptions are of central importance. It is obvious that this approach to pricing is somewhat ad hoc, but does have the advantage of being empirically tractable. Freedom of entry and exit is assumed in the non-contestable non-competitive manufacturing industries. Entry barriers other than fixed costs are ignored. A long-run equilibrium in each industry is characterized by zero economic profits in all industries, and price equal to average cost.

It should be emphasized that an important feature of the model is the interaction between scale economies, pricing rules, and entry-exit by firms. Any exogenous shock which causes firms to lower the markup on unit variable cost implies existing firms must make losses on a given volume of industry output. Thus some firms must exit, with the remaining firms producing a greater volume of output and achieving lower average costs. The adjustment at the extensive margin through entry or exit of firms is a quantitatively important impact effect of many policy changes. The actual details of any adjustment will depend upon the policy experiment being conducted, but rationalization, accompanied by changes in real wages, the volume and terms of trade, are typically the most important endogenous general equilibrium responses in the analysis of trade liberalization.

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[9] See Caves, Porter and Spence, with J.T. Scott, *Competition in the Open Economy: A Model Applied to Canada*, (Cambridge: Harvard University Press, 1980), and Baldwin and Gorecki (1986), for a summary of this literature and additional tests.

In the building and design of policy models it is important to present results in a manner which is both clear, and consistent with the underlying theoretical structure of the model. Most of the results are reported in a manner consistent with basic economic index theory, and national income accounting methodology. However, because of some of the details of the indexes are model specific, these are reviewed in chapter 3.

2.2 Commodity Definition, Aggregation Structure and Notation

The basic commodity structure of the G.E.T. model uses the identification of industries with commodities. This type of procedure, while at variance with the way in which the input-output tables are organized, is standard in economic theory, and quite useful for most purposes. Commodities are grouped into five categories, by physical type, and into three regions by location of production, as is standard in the Armington framework. Table 2.1 provides a summary of the regional/commodity structure.

Table 2.1

Commodity and Regional Structure of GET

regional sub-superscripts:

c	Canada
u	United States
r	Rest-of-World

commodity classes:

A	manufacturing import competing
B	manufacturing contestable export industries
R	resource industries (competitive)
D	non-tradeables (competitive)
E	non-competing imports

$\mathcal{C} = A \cup B \cup R \cup D \cup E$ (aggregate commodity class)

$\mathcal{M} = A \cup B \cup R \cup D$ (all domestic industries)
$\mathcal{N} = A \cup B$ (all non-competitive manufacturing)

It should be noted that while for each of the commodities in groups A, B, R, and D, there is a corresponding domestic industry, for group E, non-competing imports, there is no corresponding domestic industry. In table 2.1 the commodity class notation is to be understood as indicating the appropriate index sets for various commodities. Thus A stands for the index set of all commodities in the import competing manufacturing industries; likewise $i \in A$ indicates i is a commodity index in the commodity class A. An important integer value is the number of domestic industries, or the cardinality of the set $\mathcal{M}$. This will be denoted by N^*.

Each commodity distinguished by type and by location of production has a set of prices. There are supply or producer prices, and consumption prices distinguished by the consuming region and whether the demander of the commodity is a producer or final consumer. Before defining all relevant prices it is useful to introduce the principal tax, subsidy, tariff distortions in the model which affect various prices. All model 'distortions' are for the most part expressed in an ad valorem form, relative to the stage at which they are applied. Table 2.2 lists the relevant distortions in the GET model.[10] In table 2.3 the relationship between various commodity prices are given, as is the relevant notation for various prices.

On the factor input side there are two primary factors, capital and labour. Both labour and capital are treated as factors which are mobile across industries. The primary factor prices are w , the common supply wage, and r_j^* the supply price of rental capital services in the jth industry. These prices differ by sector because of differences in depreciation and capital composition by sector. Under the assumption that capital is internationally mobile the rental price in each sector is exogenous to the model. The producer wage and rental rates are given by

$$w_j = w\,(1 - \theta^n_j) \qquad r_j = r^*_j\,(1 - \theta^k_j)$$

In the following sections the theoretical structure of the GET model is described. For ease of exposition the model equations are written in conventional mathematical notation. As coded in the basic programs implementing the model, PILOT and TEST, the equations are the same, but use Fortran variable names. For users of the actual programs the concordance between the Fortran variable names and notation used throughout this manual is provided in Table 2.4. For reference purposes Table 2.4 should also be useful to readers of the manual, as a brief description of each symbol is provided.

2.3 Final Demand Structure

In this section the structure of the final demands in the model is laid out. As with most CGE models the final demands in GET are generated by postulating explicit maximizing behaviour on the part of the agents responsible for various components of demand. In the GET model we identify the major components of final demand as aggregate domestic expenditure, which includes consumption, investment, and government purchases from the private sector,[11] and export demands. In the case of both domestic expenditures and exports the demands are generated by assuming that a representative maximizing agent facing parametric prices and fixed income makes expenditure decisions in a utility maximizing framework. The demand functions thus generated are forced to satisfy the integrability constraints

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[10] The term 'distortions' which refers to all government instruments excluding lump sum transfers has the unfortunate and obvious value-laden connotation of being harmful. While a more neutral term might by 'policy instrument', we shall stick to the conventional terminology throughout the manual.

[11] Government purchases of labour services are not included in the version of GET described in this manual.

Table 2.2

GET Model Ad valorem Distortions

Sales taxes on final demand	τ^f
Sales taxes on intermediate demand	τ^m
Domestic export taxes	τ^x
Domestic tariffs on U.S. goods	ϕ_c^u
Domestic tariffs on R.O.W. goods	ϕ_c^r
U.S. tariffs on Canadian goods	ϕ_u^c
R.O.W. tariff on Canadian goods	ϕ_r^c
Subsidies to producers on intermediate inputs	θ^m
Subsidies to foreign consumers on export sales	θ^x
Capital expenditure subsidies	θ^k
Labour expenditure subsidies	θ^n
Fixed cost subsidies	θ^f
Producer subsidies	θ^o

Table 2.3

Prices and Pricing Identities

Producer prices by region	P^c, P^u, and P^r
Canadian consumer prices	p^c, p^u, p^r
Border supply prices of foreign goods	b^u, b^r
Export prices of Canadian goods at the border	p^x_u, p^x_r
Domestic producers intermediate goods prices	s^c, s^u, s^r
Foreign consumption prices	
(subscript-consuming region,	$q^c_u, q^u_u,$ q^r_u and
superscript-supplying region)	$q^c_r, q^u_r,$ q^r_r .
Prices exogenous to model	b^u, b^r, P^u, P^r.
All model prices	$\mathcal{P}$

Pricing Identities:

$$q^c_{iu} = p^x_{iu}(1+\phi^c_{iu})(1-\theta^x_{iu})(1+\tau^x_{iu}), \quad q^u_{iu} = P^u_i , \quad q^r_{iu} = P^r_i$$

$$q^c_{ir} = p^x_{ir}(1+\phi^c_{ir})(1-\theta^x_{ir})(1+\tau^x_{ir}) \quad q^u_{ir} = P^u_i , \quad q^r_{iu} = P^r_i$$

$$s^c_{ij} = P^c_i \, (1 + \tau^m_{ij})(1-\theta^m_{ij})$$

$$s^u_{ij} = b^u_i(1+\phi^u_{ic}) \, (1 + \tau^m_{ij})(1-\theta^m_{ij})$$

$$s^r_{ij} = b^r_i(1+\phi^r_{ic}) \, (1 + \tau^m_{ij})(1-\theta^m_{ij})$$

$$p^c_i = (1 + \tau^f_i)P^c_i \, , \quad p^u_i = (1 + \tau^f_i)(1 + \phi^u_{ic})b^u_i \, , \quad p^r_i = (1 + \tau^f_i)(1 + \phi^r_{ic})b^r_i$$

Table 2.4

Concordance of Fortran Coding and Manual Mathematical Notation for Variables in GET Model, PILOT Program

Fortran Variable	Description	Manual Symbol
A	A(I,J): use of domestic commodity I per unit output of industry J. A is domestic Leontief matrix.	a^c_{ij}
AA	Share parameter in Cobb-Douglas utility function.	μ_i
AGPROF	Aggregate "profits" accruing to all Canadian industry. "Profit" is net of opportunity cost payments to capital.	Π
ALPHA	Alpha (I,J): factor share of commodity I in industry J.	α_{ij}
	I=90 factor share of variable labour in industry J,	α_{nj}
	I=91 factor share of variable capital in industry J.	α_{kj}
ALPHAZ	Constant in Cobb-Douglas Unit Cost Function	α_{oj}
AR	AR(I): Variable capital required per unit output of industry I.	a_{ki}
ASRO	ASRO(I,J): use of R.O.W. produced commodity I per unit output of industry J.	a^r_{ij} (A^r)
ASUS	ASUS(I,J): use of U.S. produced commodity I per unit output of industry J.	a^u_{ij} (A^u)
AVGC	Average cost	AC_i
AW	AW(I): Variable labour required per unit output of industry I.	a_{wi}
AYRO	Scaling constant in R.O.W. consumption aggregator.	I^r_i (χ^n_i)
AYUS	Scaling constant in U.S. consumption aggregator.	I^u_i (χ^n_i)
BETA1	BETA(I,J): value share of domestic good I of total factor expenditure on good I in industry J and corresponding share coefficient in Cobb-Douglas unit cost function.	β^c_{ij}

BETA2	BETA2(I,J): value share of U.S. good I of total factor expenditure on good I in industry J and corresponding share coefficient in Cobb-Douglas unit cost function.	β^u_{ij} (also β^r_{ij} for R.O.W.)
BOP	net money transfer from abroad to domestic consumer	BOP
DELTA	ad valorem markup of producer prices over unit variable cost. DELTA(I)=1-MDELTA(I).	$\hat{\delta}_i$
DEM	final demand for domestic goods	D^c_i
DEMRO	final demand R.O.W. imports	D^r_i
DEMUS	final demand U.S. imports	D^u_i
DTAX	sales tax on final consumption	τ^f_i
EPS	Perceived elasticity of demand used in the monopolistic pricing rule.	ε^p_i
EXCR	Canadian export subsidy on exports to R.O.W.	θ^x_{ir}
EXCU	Canadian export subsidy on exports to U.S.	θ^x_{iu}
EXES	Price elasticity of export demand in both U.S. and R.O.W.	ε^x_{iu}, ε^x_{ir}
EXFS	Exogenous final supply of domestic commodity I	XFS_i
EXP	Value of total consumption expenditures on domestic plus foreign goods	I^c
FD	Total final demand by CHM commodity.	F_i
FI	Number of firms by industry.	ν_i
GOV	Total government revenues less subsidy payments. Included as lump-sum transfer to consumer income.	Gov
IM	Total imports by CHM commodity.	M_i
KSTOCK	Capital endowment	$\bar{K}$

L	Labour endowment	$\bar{L}$
LKR	Labour/capital ratio (value terms).	$k_j=K_j/N_j$
LR	Labour requirements (demand) by industry.	L_j^d
MDELTA	Gross markup of producer prices over unit variable cost. PR(I)=MDELTA(I) X V(I).	Δ_i
OPF	Output per firm.	y_j
PC	Final consumer price of domestic goods	p_i^c
PCSRO	Final consumer price of R.O.W. goods	$q_{iu}^r, q_{ic}^r, q_{ir}^r$
PR	Canadian Producer Prices	P^c
PRRO	R.O.W. Producer Prices	P^r
PRUS	U.S. Producer Prices	P^u
PD	PD(I,J): Price paid by producers in industry J per unit use of domestic intermediate commodity I.	s_{ij}^c
PSRO	PSRO(I,J): Price paid by producers in industry J per unit use of imported R.O.W. intermediate commodity I.	s_{ij}^r
PSUS	PSUS(I,J): Price paid by producers in industry J per unit use of imported U.S. intermediate commodity I.	s_{ij}^u
PROF	Pure profits per firm	π_i
QBRO	Border price of R.O.W. imports to Canada	b^r
QBUS	Border price of U.S. imports to Canada	b^u
R	Exogenous rental rate on a 1981 dollar of capital stock services, foreign and economy wide.	r_j
RO	Parameter in Armington CES RO=1-(1/SIGMA).	ρ_j

RODCA	Share parameter in R.O.W. commodity I CES consumption aggregator corresponding to R.O.W. expenditure on Canadian exports to R.O.W.	ψ_{ir}^{c}
RODUS	Share parameter in R.O.W. commodity I CES consumption aggregator corresponding to R.O.W. expenditure on U.S. exports to R.O.W.	ψ_{ir}^{u} (ψ_{ir}^{r})
RPRICE	Price index dual to R.O.W. (U.S.) consumption aggregator	Ψ_{ir} (Ψ_{iu})
SHRC	Share coefficient on Canadian goods in Armington CES final demand aggregator	δ_{i}^{c}
SHRUS	Share coefficient on U.S. goods in Armington CES final demand aggregator	δ_{i}^{u}
SIGMA	Armington elasticity of substitution in final demand	σ_{i}
SIGMAR	Armington elasticity of substitution in R.O.W. consumption aggregator	σ_{i}^{r}
SIGMAU	SIGMAU(I): Armington elasticity of substitution in U.S. commodity I consumption aggregator	σ_{i}^{u}
SIGPA	Perceived elasticity of substitution between foreign and domestic goods as intermediate inputs.	$\hat{\sigma}_{ij}$
SUB	Producer subsidy rate.	θ_{j}^{o}
TAX	TAX(I,J): ad valorem tax rate paid on intermediate use of commodity I by industry J.	τ_{ij}^{m}
TDRFR	Canadian tariff on R.O.W. imports	ϕ_{ic}^{r}
TDRFU	Canadian tariff on U.S. imports	ϕ_{ic}^{u}
TFRFR	R.O.W. tariff (ad valorem) on Canadian exports to R.O.W.	ϕ_{ir}^{c}
TFRFU	U.S. tariff (ad valorem) on Canadian exports to U.S.	ϕ_{iu}^{c}
UPRICE	Price index dual to U.S. CES consumption aggregator.	Ψ_{iu}
USDCA	Share parameter in U.S. commodity I CES consumption aggregator corresponding to U.S. expenditure on Canadian exports to the U.S.	ψ_{iu}^{c}

USDUS	Share parameter in U.S. commodity I CES consumption aggregator corresponding to U.S. expenditure on U.S. produced goods.	ψ^u_{iu} (ψ^n_{iu})
V	Variable cost per unit output.	v_i
W	Economy wide wage rate; W common to producers and labour suppliers (labour supply exogenous - no taxes on labour incomes).	w
X	X(I): Total output from industry I	X_i
Y	Disposable income available to consumer for expenditure on discretionary final demand expenditures.	I^c
YY	YY(I,J): intermediate use by industry J of domestically supplied commodity I	YY^c_{ij}
YYRO	YYRO(I,J): intermediate use by industry J of R.O.W. supplied commodity I	YY^r_{ij}
YYUS	YYUS(I,J): intermediate use by industry J of U.S. supplied commodity I	YY^u_{ij}

Note: In the basic programs, PILOT and TEST, the i and j are inversed (i = industry and j = commodity) for variables ASRO, ASUS, PD, PSRO, PSUS, TAX, YY, YYRO and YYUS.

imposed by maximizing behaviour, plus any structural properties imposed on the demand functions by the functional form adopted. In the case of domestic expenditures and exports however there are some problems of interpretation that require comment. In particular the conventional disaggregation of domestic final demand into consumption, investment and government expenditure is ignored. Thus all three categories of expenditure are assumed to be subject to the same influences of price and income. Compositional shifts of final demand between private sector and government, for example, are not treated. Formally it would be possible to introduce separate utility functions for each expenditure category, however this leads to a number of complications in model structure which will hopefully be addressed in future generations of the model.

2.3.1 Domestic Final Demand

Domestic final private demand is generated by postulating the existence of a representative aggregate maximizing agent, who chooses a final demand vector D by maximizing a logarithmic (Cobb-Douglas) utility function

$$\log U = \log \mu_0 + \sum_{i \in \mathcal{G}} \mu_i \log C_i \tag{3.1}$$

The μ_i are share parameters over the commodity aggregates C_i. The GET model uses, as described previously, the Armington assumption, that goods within the same commodity class, but produced in different regions are viewed as different, but highly substitutable goods by those consuming them. With respect to domestic final demand C_i is a CES aggregate of goods produced in Canada, the United States and R.O.W. Specifically the Armington sub-aggregate utility function over Canadian, U.S., and R.O.W. commodities within commodity class $i \in \mathcal{G}$, with substitution parameter $\rho_i = 1 - 1/\sigma_i$, is given by

$$C_i = \left[\delta_i^c {D_i^c}^{\rho_i} + \delta_i^u {D_i^u}^{\rho_i} + \delta_i^r {D_i^r}^{\rho_i} \right]^{\frac{1}{\rho_i}} \tag{3.2}$$

Domestic final demand functions for domestic output, D_i^c, U.S. produced output, D_i^u, and R.O.W. produced output, D_i^r, are derived by first maximizing the C_i functions subject to the constraint that the expenditure on commodity class i is fixed, and then allocating expenditure across commodity classes to maximize U. It is well known that with the Cobb-Douglas structure the expenditure share on commodity class i is given by μ_i.[12] Thus $\mu_i I^c$ is the total income allocated to expenditure on commodity class i. This two-stage budgeting procedure leads to the demand functions

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[12] This assumes the μ_i have been normalized such that $\sum_{i \in \mathcal{G}} \mu_i = 1$.

$$D_i^c = \frac{\mu_i I^c \delta_i^{c^{\sigma_i}} p_i^{c^{(-\sigma_i)}}}{\delta_i^{c^{\sigma_i}} p_i^{c^{(1-\sigma_i)}} + \delta_i^{u^{\sigma_i}} p_i^{u^{(1-\sigma_i)}} + \delta_i^{r^{\sigma_i}} p_i^{r^{(1-\sigma_i)}}} \tag{3.3}$$

$$D_i^u = \frac{\mu_i I^c \delta_i^{u^{\sigma_i}} p_i^{u^{(-\sigma_i)}}}{\delta_i^{c^{\sigma_i}} p_i^{c^{(1-\sigma_i)}} + \delta_i^{u^{\sigma_i}} p_i^{u^{(1-\sigma_i)}} + \delta_i^{r^{\sigma_i}} p_i^{r^{(1-\sigma_i)}}} \tag{3.4}$$

$$D_i^r = \frac{\mu_i I^c \delta_i^{r^{\sigma_i}} p_i^{r^{(-\sigma_i)}}}{\delta_i^{c^{\sigma_i}} p_i^{c^{(1-\sigma_i)}} + \delta_i^{u^{\sigma_i}} p_i^{u^{(1-\sigma_i)}} + \delta_i^{r^{\sigma_i}} p_i^{r^{(1-\sigma_i)}}} \tag{3.5}$$

Final demand imports are D_i^u and D_i^r, while domestic final demand for the domestically produced good is D_i^c. The distinguishing characteristic of these demand functions is that the income elasticity of demand for all products is unity, given the homogeneous utility function. The own price elasticity of demand for Canadian good i is

$$\varepsilon_c^d = -\sigma_i + s_i^c(\sigma_i - 1) \tag{3.6}$$

where s_i^c is the share of expenditure within commodity class i spent on the domestic good. As the Armington substitution elasticity σ^i is greater than 1, the own price elasticity of demand exceeds one in absolute value provided s_i^c is sufficiently small.

The combined Cobb-Douglas/Armington functional form is very convenient for both computational and calibration procedures. While it is possible to use more flexible functional forms they require more detailed price elasticity estimates than are often available.

In a static long-run GE model such as GET there are often questions about the interpretation of savings and investment. Strictly speaking within a static model there are no savings. The interpretation usually given the static model however is that expenditure activities encompass investment and therefore the traditional price and income influences of microeconomic theory also apply to investment as well as consumption expenditures. The utility or real income derived from investment is reflected in the parameters pertaining to investment goods within the overall utility function. Clearly this is less than completely satisfactory, and an alternative, short of going to a complete dynamic model, is to introduce a savings/consumption function.[13] Within GET the Cobb-Douglas functional form has the practical implication that the share of national expenditure spent on investment goods is constant. This could be rationalized as a type of Keynesian savings function, with savings equal to investment.

A different issue pertaining to the functional form is the omission of aggregation effects on aggregate demand. Thus if a policy shifts income from the rich to the poor, the implicit assumption is that the marginal propensity to consume of the rich is equal to the poor, which in turn means that any shift in the distribution of income is neutral with respect to its impact on aggregate expenditure patterns. This assumption is well known from trade theory; explicitly it means that all consuming groups resident within the country must have identical homothetic preference or utility functions. An obvious benefit of this assumption is that it allows one to use representative agent measures of national welfare, such as consumer surplus, with a straightforward interpretation.[14]

The treatment of exports within this version of GET differs in substantial ways from previous versions of GET.[15] The earlier model followed a well known tradition in CGE of using constant elasticity export demand equations. In this version of GET a more restrictive form of export demand was adopted, which is closer in spirit to the full world scale Armington models of Whalley (1985) or Deardorff and Stern (1979) for example. Specifically the assumption is made that the U.S. and R.O.W. regions have expenditure behaviour which can be summarized by exogenous aggregate expenditures on each particular commodity category i. These in turn could be rationalized as coming from Cobb-Douglas trade utility functions over the commodity classes in $\mathcal{C}$,[16] together with a fixed aggregate income level in each region. Within each commodity class i the trade utility function has sub-utility aggregators of the Armington form, aggregating utility from Canadian, U.S., and R.O.W. goods within the same class i. Given a sub-utility level U_i^g in region g, it is convenient to describe these sub-utility indicators by the corresponding expenditure function,

$$I_i^u(Q_i^u, U_i^u) = U_i^u \left[\psi_{iu}^{c\,\sigma_i^u} \, q_{iu}^{c\,(1-\sigma_i^u)} + \psi_{iu}^{u\,\sigma_i^u} \, q_{iu}^{u\,(1-\sigma_i^u)} + \psi_{iu}^{r\,\sigma_i^u} \, q_{iu}^{r\,(1-\sigma_i^u)} \right]^{\frac{1}{(1-\sigma_i^u)}} \qquad (3.7)$$

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[13] The World Bank has pursued this approach in a number of their models. See Dervis el. al. (1982) for a discussion of the savings-investment issue.

[14] This will be explained further in chapter 3, section 2.

[15] As used for example in Harris (1984a) or Cox and Harris (1985).

[16] For an exposition of the trade utility function see Woodland (1982), chpt. 6.

$$I_i^r(Q_i^r,U_i^r) = U_i^r\left[\psi_{ir}^{c\,\sigma_i^r}\, q_{ir}^{c\,(1-\sigma_i^r)} + \psi_{ir}^{u\,\sigma_i^r}\, q_{ir}^{u\,(1-\sigma_i^r)} + \psi_{ir}^{r\,\sigma_i^r}\, q_{ir}^{r\,(1-\sigma_i^r)}\right]^{\frac{1}{(1-\sigma_i^r)}}. \qquad (3.8)$$

Given that the underlying sub-utility functions are homogeneous CES functions it is possible to decompose the expenditure function into a price index and utility level. The price indexes are concave, increasing homogeneous of degree one functions in prices Q_i given by

$$\Psi_i^u = \left[\psi_{iu}^{c\,\sigma_i^u}\, q_{iu}^{c\,(1-\sigma_i^u)} + \psi_{iu}^{u\,\sigma_i^u}\, q_{iu}^{u\,(1-\sigma_i^u)} + \psi_{iu}^{r\,\sigma_i^u}\, q_{iu}^{r\,(1-\sigma_i^u)}\right]^{\frac{1}{1-\sigma_i^u}} \qquad (3.9)$$

$$\Psi_i^r = \left[\psi_{ir}^{c\,\sigma_i^r}\, q_{ir}^{c\,(1-\sigma_i^r)} + \psi_{ir}^{u\,\sigma_i^r}\, q_{ir}^{u\,(1-\sigma_i^r)} + \psi_{ir}^{r\,\sigma_i^r}\, q_{ir}^{r\,(1-\sigma_i^r)}\right]^{\frac{1}{1-\sigma_i^r}} \qquad (3.10)$$

Recalling that expenditure on all commodity categories $i \in \mathcal{M}$ in the U.S. and R.O.W. is exogenous, consumer equilibrium in both these regions requires the following identities between utility levels, price indexes and expenditure levels:

$$\Psi_i^u\, U_i^u = I_i^u \qquad \text{and} \qquad \Psi_i^r\, U_i^r = I_i^r \qquad (3.11)$$

Using Shepherd's lemma, and substituting (3.11) yields the demand by the U.S. and R.O.W. for Canadian exports.

$$E_i^u = I_i^u\, \psi_{iu}^{c\,\sigma_i^u}\, q_{iu}^{c\,-\sigma_i^u}\, \Psi_{iu}^{(\sigma_i^u-1)} \qquad (3.12)$$

$$E_i^r = I_i^r\, \psi_{ir}^{c\,\sigma_i^r}\, q_{ir}^{c\,-\sigma_i^r}\, \Psi_{ir}^{(\sigma_i^r-1)} \qquad (3.13)$$

Note that in this particular formalization of export demands, the Armington substitution elasticity, σ_i^u for example, plays a role exactly analogous to the domestic Armington elasticity in the structure of domestic final demand. Also analogous is the fact that income elasticities of export demand are unity for all goods.

The major virtue of this particular formalization of export demand is that it is symmetric with the treatment of domestic final demand, and is consistent with a larger theoretical model of world general equilibrium. In actual simulations I^r and I^u are treated as exogenous; thus world expenditures by commodity are treated as if they are independent of influence by changes in Canadian prices or G.N.P. This is a convenient but perhaps not entirely accurate assumption for many goods.

Within the model it is important to realize the role of these export demand functions. In large part they are the most important determinant of the volume and terms of trade changes within the model. Together with the assumption that the supply of imports to Canada is perfectly elastic they describe the offer curves facing the Canadian economy. Furthermore, although not specified here, there are implicit import demand curves by the U.S. and R.O.W. for each other's goods. Thus any policy experiment which changes relative supply prices in Canada will have repercussions on these international goods flows. As a practical matter this is only of importance if the Canadian supply is a significant share of one region's total expenditure on a particular commodity class. GET does not focus on any non-Canadian exports, as the model is not designed to do this in any detail; nevertheless these third country effects can be important, and should be kept in mind.

Summarizing, the final demand for domestic commodity i (F_i)is given by

$$F_i = D_i^c + E_i^u + E_i^r - XFS_i. \tag{3.14}$$

XFS_i is exogenous final supply, and is used in benchmark simulations to account for what is regarded as unusual changes in inventory in a benchmark year. It can also be used as a dummy variable to calculate the shadow prices of particular commodities.[17] For most policy simulations XFS_i is set equal to zero. This completes the discussion of final demands.

2.4 Output, Intermediate and Primary Factor Demands

In this section of the manual the structure of technology, intermediate input demands for domestic and imported goods is described, and basic consistency conditions on gross outputs and domestic commodity prices are derived. This section also discusses primary factor demands, and the important distinction between fixed and variable factor inputs.

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[17] The 'shadow utility price' of commodity i is defined as the increase in utility U given a unit increase in the exogenous available supply of commodity i. Relative shadow prices can be compared with relative market prices as an indication of the divergence between social and private opportunity cost. They are also useful if the model is to be used for cost benefit analysis.

2.4.1 Technology

Industries are divided into two groups, the constant returns, competitive industries consisting of groups R and D; and the potentially non-competitive increasing returns sector groups A and B. Under the assumption of competitive constant returns there is no necessity to detail individual plant or firm technology, but rather it suffices to describe technology of the *industry* by a conventional constant returns neoclassical production function. Each industry is presumed to use intermediate inputs, labour and capital to produce a single output. This technology is conveniently summarized by a *unit cost function* v_j for industry j,

$$v_j(s^c, s^u, s^r; w_j, r_j) \tag{4.1}$$

This cost function is a homogeneous, concave, increasing function of the prices of intermediate inputs, s^c, s^u, s^r, labour, w_j, and capital service rentals, r_j. In this version of GET the particular functional form chosen for $v_j(\cdot)$ is the Cobb-Douglas, with Cobb-Douglas aggregators over domestic, U.S. and R.O.W. produced materials. Thus

$$\log v_j = \gamma_{oj} + \sum_{i \varepsilon \mathcal{G}} \alpha_{ij} \log \Gamma_{ij} + \alpha_{nj} \log w_j + \alpha_{kj} \log r_j \tag{4.2}$$

The price index for intermediate material i in industry j, Γ_{ij}, is given by

$$\log \Gamma_{ij} = \log \gamma^o_{ij} + \beta_{ij} \log s^c_{ij} + \beta^u_{ij} \log s^u_{ij} + \beta^r_{ij} \log s^r_{ij}. \tag{4.3}$$

With this functional form α_{ij} is necessarily material i's share of total cost in industry j, while β^c_{ij} is the share of total material cost i accounted for in industry j by the Canadian produced material i. Homogeneity implies that the coefficients satisfy

$$\Sigma_{i \varepsilon \mathcal{G}} \alpha_{ij} + \alpha_{nj} + \alpha_{kj} = 1 \tag{4.4}$$

Within the A and B industries there is a distinction between firms and industries. Each firm within a given industry has an identical technology characterized by decreasing average costs of production. More specifically the representative firms's technology is characterized by the existence of fixed and variable costs *in the long run*. The fixed costs are labour and capital costs which must be incurred to set up a representative plant capable of producing a positive level of output. Variable costs however are constant per unit of output for given input prices. Thus for an output level of y_j of a firm in industry j its *total cost function* is given by

$$TC_j(s^c,s^r,s^u,w_j,r_j;y_j) = FC_j(w_j,r_j) + v_j(s^c,s^u,s^r;w_j,r_j)y_j \qquad (4.5)$$

$FC_j(\cdot)$ is the fixed cost function and $v_j(\cdot)$is now interpreted as the *variable unit cost function*. This type of cost function exhibits an average cost curve which is falling everywhere, and asymptotic to v_j as y_j tend to large values.[18] The great simplicity offered by this cost function lies in the fact that the demand for intermediates by the industry can be determined simply by multiplying demand per unit output, which is given by the appropriate derivative of the variable unit cost function, times industry output. Thus because the demand for intermediate inputs is linearly homogeneous in output for all industries the conventional Leontief calculations are still valid. However, in calculating the industry demands for labour and capital it will be necessary to account for both the number of firms in the industry, and the output per firm.

The input/output coefficients for domestic intermediates and imported intermediates are derived by Shephard's lemma from (4.2) and (4.3):

Domestic input coefficients $$a^c_{ij} = \frac{\alpha_{ij}\beta^c_{ij}v_j}{s^c_{ij}} \qquad (4.6)$$

U.S. input coefficients $$a^u_{ij} = \frac{\alpha_{ij}\beta^u_{ij}v_j}{s^u_{ij}} \qquad (4.7)$$

R.O.W. input coefficients $$a^r_{ij} = \frac{\alpha_{ij}\beta^r_{ij}v_j}{s^r_{ij}} \qquad (4.8)$$

Letting X denote the vector of gross industry outputs in sector, imported intermediate input vectors (N^r and N^u) are given by

U.S. $$N^u = A^uX \qquad \text{with } A^u = (a^u_{ij}\ ) \qquad (4.9)$$

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[18] We shall often refer to this class of cost functions as *hyperbolic cost functions* (HBCF); the issue of approximating general cost functions with hyperbolic cost functions is taken up in chapter 5.

R.O.W. $N^r = A^r X$ with $A^r = (a^r_{ij})$. (4.10)

The Leontief relationship between final demand and total output of domestic commodity i is given by

$$X_i = F_i + \sum_{j \in M} a^c_{ij} X_j, \tag{4.11}$$

where $\sum_{j \in M} a^c_{ij} X_j$ is the use of domestically produced material i by all other domestic industries, given the vector X of total domestic outputs. This is written in vector form as: (all vectors are taken to be column vectors.)

$$X = F + (A^c)X \qquad \text{or} \qquad X = [I - (A^c)]^{-1} F \tag{4.12}$$

Output decomposition into domestic use and export sales can be conveniently written as

$$X = X^c + E^u + E^r \tag{4.13}$$

where X^c denotes the vector of outputs for domestic use.

Within the constant returns R and D industries demands for capital and labour services, as functions of prices and outputs, are determined by conventional factor demand equations. Thus given industry output X_j of industry j, and the vector of all prices $\mathcal{P}$ the demand for labour and capital services are

$$L_j(\mathcal{P}, X_j) = a_{nj} X_j \qquad K_j(\mathcal{P}, X_j) = a_{kj} X_j \tag{4.14}$$

where the unit labour and capital requirements coefficients are respectively given by

$$a_{nj} = \frac{\alpha_{nj} v_j(\mathcal{P})}{w_j} \tag{4.15}$$

and

$$a_{kj} = \frac{\alpha_{kj} v_j(\mathcal{P})}{r_j} \tag{4.16}$$

In the A and B sectors it is necessary to specify the structure of fixed costs to determine the total industry demand for labour and capital. The fixed cost function is assumed to be linear in factor prices, or equivalently there is an exogenous amount of capital and labour required per firm. Denoting these quantities by ω_{ni} (fixed labour requirements) and ω_{ki} (fixed capital requirements), the fixed cost function is given by

$$FC_j(w_j, r_j) = w_j\omega_{nj} + r_j\omega_{kj}. \tag{4.17}$$

Hence if there are ν_j identical firms in industry j, the demand for labour in industry j is given by

$$L_j(P, \nu_j, X_j) = \nu_j\omega_{nj} + a_{nj}X_j \tag{4.18}$$

where a_{nj} is given by (4.15). Likewise capital service demand in the A and B industries is given as

$$K_j(P, \nu_j, X_j) = \nu_j\omega_{kj} + a_{kj}X_j \ . \tag{4.19}$$

2.4.2 Commodity Price Structure

It is well known that in long run equilibrium in constant returns industries prices in all industries and on all factors of production must be such that the condition average cost equal price (adjusting for tax or subsidy distortions) is satisfied. Within the GET model an analogous condition is given, once it is recognized that in the A and B industries v_j is also marginal cost of production. If it is assumed that prices in these industries are set by markups on marginal cost, then there is a relationship between the price of output in the jth industry, the markup, and the unit variable cost function $v_j(\cdot)$. As discussed in section 3.6 on pricing theories, the model used for pricing in imperfectly competitive markets ultimately reduces to a gross markup Δ_j of price on unit or marginal cost in industry j. In the constant returns competitive industries price must equal average cost plus or minus any tax/subsidy levied on the producer. Thus the pricing equations for domestic producer prices P^c are[19]

Manufacturing $\quad P_i^c = \Delta_i v_i$

Non-manufacturing $\quad P_i^c = (1-\theta_i^o)v_i.$

The pricing equations in vector form with $Z=(S^u, S^r, w, r)$, are

$$P^c = \Delta\, v(P^c,\ Z) \tag{4.20}$$

where $v(\cdot)$ is a stacked vector of unit cost functions of dim $|\mathcal{M}| = N^{\#}$ and Δ

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[19] θ_j^o is the producer subsidy per unit output on industry j. Note that Δ_i is defined such that the markup is inclusive of the producer subsidy. See section 6 on pricing.

is a diagonal matrix with the markups by industry on the diagonal and zeros elsewhere. Z denotes all prices and parameters entering the cost functions other than P^C. For the constant return industries the markups in Δ are defined as 1 minus the net subsidy rate. Equation (4.20) describes the relationship which must hold if commodity prices are consistent with equilibrium and the basic pricing theory of the model. Technically (4.20) is $N^{\#}$ non-linear equations in $N^{\#}$ variables, and as such can be solved for a solution vector P^C; the solution vector P^C is a function of the parameters Δ and Z. A number of solution methods can be used to solve for P^C.[20] Both equations (4.12) and (4.20) provide important reductions in the dimensionality of the overall equilibrium problem.

2.5 Quasi-Equilibrium

In this section of the paper the properties of a short-run *quasi equilibrium*, defined as a situation in which industry structure variables are held constant, but all commodity and factor markets clear, is elaborated upon. A quasi equilibrium is a fictional device used to organize accounting within the GET model and is not to be confused with the conventional short-run equilibrium of Marshallian economics. The Marshallian short-run is defined as a period of real calendar time during which prices are flexible, but capital stocks are regarded as fixed. In the GET *quasi equilibrium* the industrial structure is held fixed, but the quantity of non-fixed-cost capital services can vary. However like the Marshallian short run the GET *quasi equilibrium* is characterized by the existence of economic profits or losses in the A and B industries *only*. As price is set equal to average cost, profits are identically zero in all R and D industries.[21]

The industrial structure variables are defined as the number of firms in each of the B and D industries, plus the vector of markups in these industries. Denote industrial structure therefore as $\mathcal{I} = (\nu, \Delta)$.

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[20] It is possible to prove that with mild regularity conditions on the cost functions v_j, and the traditional Hawkins-Simons productivity condition on the A^C matrix, that a solution exists and is unique. A convenient solution method is the iterated cost function mapping, defined by

$$P_{t+1} = \Delta\ v(P_t, z) \qquad\qquad P_o = \bar{P}.$$

For arbitrary positive $\bar{P}$ it can be shown that $\lim_{t\to\infty} P_t = P^*$ is a solution to (4.20). See chapter 6, Appendix 1.

[21] Profit is defined as revenues minus costs plus subsidies. Since the producer price is corrected for any output subsidy, profit in the R and D industries is exactly zero.

Definition A *quasi equilibrium* relative to an industrial structure $\mathcal{I}$ is an economy wide wage, w, a vector of domestic prices P^c, and a vector of domestic outputs, X such that

1) the aggregate labour market clears
2) price equals average cost less unit subsidy in the R and D industries
3) price equals a gross markup Δ_j on unit cost in all $\mathcal{N}$ industries
4) supply equals demand in all domestic commodity markets $\mathcal{M}$

To elaborate further on the properties of a *quasi equilibrium* it is necessary to define some general equilibrium notions of income and supply. Given a set of prices $\mathcal{P}$, and income I^c, utility maximization yields a set of final demands. Given final demands and prices it is possible to find, using cost-minimizing input choices, a vector of gross outputs X, which will clear all commodity markets by equation (4.12). In turn given this vector of gross outputs and using factor requirements coefficients (4.15) (4.16), and knowledge of the industrial structure $\mathcal{I}$ the aggregate factor demand equations for labor and capital services are,

$$K^D = \sum_{j \in \mathcal{M}} a_{kj} X_j + \sum_{j \in \mathcal{N}} \nu_j \omega_{kj} \tag{5.1}$$

$$L^D = \sum_{j \in \mathcal{M}} a_{nj} X_j + \sum_{j \in \mathcal{N}} \nu_j \omega_{nj} . \tag{5.2}$$

Income in any GE model is not exogenous. To give an appropriate general equilibrium definition of income it is necessary to lay out in some detail the structure of resource ownership, and government tax-subsidy-transfers. A major component of income, is labour income derived from the sale of labour services. Domestic households in aggregate are endowed with a quantity of labour services $\bar{L}$ which is sold at a common wage w to all demanders of labour services. This labour is supplied completely inelastically. Households in addition own claims to a homogeneous asset we shall call capital which provides an aggregate flow income of DKY. In a quasi equilibrium as economic profits are positive or negative, it is important to be explicit about the ownership structure of domestic industry. It is assumed that domestic residents own an exogenous fraction Λ_i of each domestic industry $i \in \mathcal{M}$. Note that economic profits are defined distinctly from returns to capital. Capital is treated on an 'as if' rental basis. Thus all firms' economic costs are net of opportunity cost payments to capital. For a given vector of prices, industrial structure variables, and outputs, economic profits are thus defined as revenues minus costs.

Producer net revenues by industry are

$$Rev_i = P_i^c \, (1+\theta_i^o) X_i^c + p_{iu}^x E^u + p_{ir}^x E^r . \tag{5.3}$$

Total industry cost, inclusive of both variable and fixed costs, is given by

$$\mathrm{Cost}_i = v_i X_i + \nu_i (r_i \omega_{ki} + w_i \omega_{ni}) \tag{5.4}$$

Economic profit in industry i is thus given by

$$\Pi_i = \mathrm{Rev}_i - \mathrm{Cost}_i \ . \tag{5.5}$$

Thus income accruing to domestic households, due to their ownership claims on domestic industry is given by

$$\mathrm{Agprof} = \Sigma_{i \varepsilon \mathcal{M}} \Lambda_i \Pi_i \tag{5.6}$$

Economic profits in a quasi equilibrium will be zero in the R and D industries only. Economic profits in the A and B industries will generally be non-zero because of the arbitrary nature of the number of firms and the markups in those industries.

Much of the structure of the GET model is concerned with government distortions and these distortions result in the government both taking in receipts and incurring expenditures. To preserve general equilibrium consistency, any net receipts from government activities must returned in some fashion to domestic spending agents. Within the GET model we adopt the convenient assumption that all net government receipts are returned (or levied) in a lump sum fashion on domestic households. This assumption common in CGE literature of international trade is adopted because of the simplicity of implementation, and because it does not require an explicit mechanism by which changes in one part of the government budget constraint are matched by changes elsewhere. With respect to tariff cuts for example it means that the loss in tariff revenue is made up by smaller lump sum transfers. One could consider alternative assumptions such as a constant real government budget, with all compensating changes made through adjustment of a uniform sales tax. This is however not common in the applied trade literature, and it is convenient to stick with the simpler assumption.

Government receipts and disbursements from distortions come from a variety of sources. These are:

(1) Tariff revenue

$$\mathrm{Tariff} = \sum_{i \varepsilon \mathcal{C}} b_i^u \phi_{ic}^u M_i^u + b_i^r \phi_{ic}^r M_i^r$$

(2) Intermediate material subsidies

$$\mathrm{Msub} = \sum_{i \varepsilon \mathcal{C}} \sum_{j \varepsilon \mathcal{M}} \left(1+\tau_{ij}^m\right) \theta_{ij}^m \left[P_i^c \, YY_{ij}^c + b_i^u \left(1+\phi_{ic}^u\right) YY_{ij}^u + b_i^r \left(1+\phi_{ic}^r\right) YY_{ij}^r\right]$$

(3) Tax revenue on final demand

$$Txfin = \sum_{i\in\mathcal{C}} \tau^{f}_{i}\left(P^{c}_{i}\,D^{c}_{i} + b^{u}_{i}(1 + \phi^{u}_{ic})D^{u}_{i} + b^{r}_{i}(1 + \phi^{r}_{ic})D^{r}_{i}\right)$$

(4) Tax revenue on intermediate inputs

$$Txint = \sum_{i\in\mathcal{C}}\ \sum_{j\in\mathcal{M}} \tau^{m}_{ij}\left(1-\theta^{m}_{ij}\right)\left[P^{c}_{i}\,YY^{c}_{ij} + b^{u}_{i}\left(1+\phi^{u}_{ic}\right)YY^{u}_{ij} + b^{r}_{i}\left(1+\phi^{r}_{ic}\right)YY^{r}_{ij}\right]$$

(5) Export tax revenue

$$Txexp = \sum_{i\in\mathcal{M}} \tau^{x}_{iu}\,P^{x}_{iu}E^{u}_{i} + \tau^{x}_{ir}P^{x}_{ir}E^{r}_{i}$$

(6) Export subsidies

$$Exsub = \sum_{i\in\mathcal{M}} \theta^{x}_{iu}\left(1+\tau^{x}_{iu}\right)P^{x}_{iu}\,E^{u}_{i} + \theta^{x}_{ir}\left(1+\tau^{x}_{ir}\right)P^{x}_{ir}\,E^{r}_{i}$$

(7) Capital and labour subsidies

$$Ksub = \sum_{j\in\mathcal{M}} \theta^{k}_{j}\,r^{*}_{j}K_{j}$$

$$Lsub = \sum_{j\in\mathcal{M}} \theta^{n}_{j}\,wL_{j}$$

(8) Fixed cost subsidies

$$Fcsub = \sum_{j\in\mathcal{M}} \theta^{f}_{j}\left(r_{j}\nu_{j}\omega_{kj} + w_{j}\nu_{j}\,\omega_{nj}\right)$$

(9) Producer subsidies

$$Sub = \sum_{j\in\mathcal{M}} \theta^{o}_{j}\,P_{j}\,x_{j}$$

Adding these nine different items together yields net government revenue, which is returned to domestic private agents as a lump sum transfer (GOV)

$$GOV = Tariff + Txfin + Txint + Txexp - Msub - Ksub - Lsub - Fcsub - Exsub - Sub \qquad (5.7)$$

Domestic private income, I^{c}, is the sum of labour income, asset income, economic profits on domestic industry, and net government transfers. This is income all of which will be spent by private domestic agents on consumption or investment.

$$I^c = w\bar{L} + \sum_{i \in \mathcal{M}} \Lambda_i \Pi_i + GOV + r\bar{K} \tag{5.8}$$

Note that income itself is a function of wages, prices $\mathcal{P}$, and outputs X. Hence income I^c must be determined endogenously within the model.

2.6 Numéraires, Capital Flows and Balance of Payments

As is well known any model such as this which uses budget constraints as a principal feature of model structure will satisfy some form of Walras' law. It will be convenient at this point to discuss this in terms of its implications for capital flows and balance of payments.

Recall the basic assumption that all imports are supplied perfectly elastically at exogenous foreign prices. Within the model, as in most of small open economy international trade, the numéraire goods are imported commodities selling at exogenous prices. For convenience we measure these prices in terms of a common currency unit we shall refer to as "dollars". Statistically these could be identified with the Canadian dollar price of imports in a particular base year, although it is important to keep in mind that these must be interpreted as real foreign commodity prices. For this reason perhaps we can adopt the fiction of measuring all external transactions in U.S. dollars. Thus all prices are to be thought of as measured against these exogenous foreign currency prices.[22]

The model is *closed* by assuming that there is a foreign asset market which sets the rental rates on real capital goods at r_j^* dollar per year in each sector $j \in \mathcal{M}$. The capital good is defined as a homogeneous capital good, the services of which are an input to all firms' production in sector j. The services of this capital good can be imported or exported in any quantity at the price r_j^*. This assumption is the model equivalent version of the assumption that capital is perfectly mobile across borders. Canada is thus viewed as a strict price-taker in world capital markets. It is convenient to think of the fixed rental rate on services of real capital as being consistent with the assumption of a fixed world real interest rate. Some of domestic capital income may derive from ownership of domestic assets which are claims against capital used for production within domestic industries, and some of it may be derived from the ownership of foreign assets.

External flows thus involve both goods flows, exports and imports, plus capital service flows. Net capital service imports, VKM, are summarized as the (value) difference between the total payments for real capital services, as measured by the aggregate capital demand equation, and the total domestic asset income.

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[22] Of course an actual change in a domestic producer price could occur because of either a change in the Canadian exchange rate against U.S. dollars, or because of a shift in the nominal Canadian price at a constant exchange rate.

$$VKM = \Sigma_{j\varepsilon\mathcal{M}} r_j^{*} K_j^{D} - DKY \qquad (6.1)$$

Aggregate imports are

U.S. $M_i^u = D_i^u + N_i^u$

R.O.W. $M_i^r = D_i^r + N_i^r$

which imply a gross import bill of

$$Mbill = \Sigma_{i\varepsilon\mathcal{G}} b_i^u M_i^u + b_i^r M_i^r \qquad (6.2)$$

Likewise total export receipts are given by

$$Ebill = \Sigma_{i\varepsilon\mathcal{M}} p_{iu}^x E_i^u + p_{ir}^x E_i^r \qquad (6.3)$$

The trade surplus on merchandise trade and services[23] is thus given by

$$SURP = Ebill - Mbill. \qquad (6.4)$$

The balance of payments is defined as the trade surplus minus capital service imports. A *balance of payments equilibrium* is thus defined as a situation in which the trade surplus plus transfers from foreigners equals capital service imports. An important property of the model is that in a *quasi equilibrium* the balance of payments is always in equilibrium. This is a straightforward property of adding up the budget constraints of all individual agents, and noting the definition of of economic profits of individual firms. In the GET model it is the analogue of Walras law.[24] Because the balance of payments equilibrium condition is implied by the other equilibrium conditions as listed in the definition of a *quasi-equilibrium* it is not necessary in the computation of a *quasi equilibrium* to explicitly impose a balance of payments equilibrium condition. This of course is of some value in reducing the computational complexity of the model.

2.7 Pricing Theory

In this section of the paper the important question of pricing rules in the non-competitive manufacturing industries is addressed. Within the model three alternative forms of pricing rules are considered. First,

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[23] Note that service exports and imports are not included with capital flows. Thus tourism, for example, is recorded under the trade account. Interest and dividend payments however are implicity included under capital service net imports.

[24] A proof of this proposition is provided in an appendix.

Eastman-Stykolt pricing within import competing industries is discussed, then monopolistic competition pricing which is a general form of non-competitive pricing rule which utilizes demand elasticity information, and finally Contestable pricing which is essentially average cost pricing applicable to export industries. Each of these type of pricing mechanisms will be taken up in turn.

2.7.1 Eastman-Stykolt Pricing

The study of pricing within import competing manufacturing industries has a long history both within Canada, and abroad. Within Canada the most famous of the pricing hypotheses is due to Eastman and Stykolt and published in their 1967 book The Tariff and Competition in Canada. The main hypothesis advanced in this book was that in high tariff industries where economies of scale were sufficiently important to justify only a few domestic firms servicing the market, prices were set within the industry by simply using world price plus tariff as a 'focal point' price. It is important to emphasize that this rule was justified not as the outcome of a rational profit maximizing collusive cartel, but as a simple but effective way to coordinate pricing within a small numbers oligopoly in a visible and effective way. Subsequent empirical research has led considerable weight to the Eastman-Stykolt hypothesis and remains probably the most relevant pricing framework within import competing manufacturing.

The Eastman-Stykolt gross markup of producer prices over unit costs, Δ_i^{ES} is defined as

$$\Delta_i^{ES} = \frac{(1 + \phi_{ic}^{u})b_i^{u}}{v_i} \tag{7.1}$$

With pure Eastman-Stykolt pricing then the domestic producer price would be

$$P_i^{c} = \Delta_i^{ES} v_i \tag{7.2}$$

Note that the Eastman-Stykolt hypothesis suggests a causal link which runs directly from foreign prices plus tariffs to domestic prices and costs. In this respect it is much like the price taking hypothesis used in the small open economy literature where all demand and supply curves facing the economy are assumed to be perfectly elastic. In this case the presumption is that the foreign firms selling at b_i^{u} are willing to supply all that the domestic economy is willing to absorb.

Within the context of the G.E.T. model there are at least two points worth making about the Eastman-Stykolt rule. First is the issue about the relevant region of foreign supply. Within the G.E.T. model this could be either the U.S. or R.O.W. The working assumption adopted is that the region supplying the largest share of imports is the region for which the relevant Eastman-Stykolt reference price is taken. In most cases this will be the U.S. price, although not in all cases. The second issue is both an empirical and analytical one. In principle the 'price' which is relevant is for the closest competing foreign product. Under the Armington demand assumption the foreign and domestic product are imperfect substitutes, although they must obviously be close substitutes in the eyes of buyers. The Eastman-Stykolt pricing rule makes no allowance for the cross elasticity of demand between the foreign and domestic good. Prices are set 'as if' the two goods were perfect competitors. Again this assumption can be defended as reasonable pricing behaviour within a close knit oligopoly producing closely competing products, or as a useful simplification of unobserved but possibly complex pricing behaviour within protected oligopolies. Empirically at the level of commodity aggregation used within the model there is considerable difficulty in taking the Eastman-Stykolt rule literally. In practice within a given commodity class there will be some commodities for which the rule obviously applies and others for which it is less relevant.

2.7.2 Monopolistic Competition Pricing

Within the traditional theory of oligopoly commonly applied to closed economy industry models there are a variety of pricing hypotheses which have emerged as a result of differing assumptions about conditions of entry, the extent of product differentiation, the degree of imperfect information between rival firms, and the nature of the oligopolistic game firms perceive themselves to be engaged in. To complicate matters further, within a general equilibrium framework there has been considerable debate over the years as to the extent nature of the demand curve facing the firm. This debate revolves around what the firm can be assumed to know, and what they can take as usefully exogenous to their own price and quantity decisions. It is not the purpose of this section to review all theories of oligopolistic pricing. There is however one basic alternative pricing rule which comes out of the Chamberlin-Cournot theory of monopolistic competition which can be applied in a suitably amended fashion to a general equilibrium model. It is worth remarking that it is this theory which is used extensively in the work of Helpman and Krugman (1985) on trade and imperfect competition.

For the sake of brevity the monopolistic competition pricing rules will henceforth be referred to as MCH pricing. The basic idea is that each individual firm faces a demand curve for its product given by

$$d = \alpha p^{-\varepsilon} \tag{7.3}$$

where d is the demand for an individual firm within the industry in question, and p is the individual firm's price for its own product. The functional form for demand is an iso-elastic function for which the price elasticity of demand is $-\varepsilon$ everywhere. For reasons of internal consistency ε must be positive and greater than one. The theory of monopolistic competition achieves its simplicity by relating market demand to individual firm demand. There are two common ways of doing this. One is to use the proportionality hypothesis which assumes that all firms in a given industry produce perfectly homogeneous goods and that each firm takes the total output produced by all other firms as given. This assumption results in the famous Cournot pricing rule where individual firm demand elasticity ε is given by

$$\varepsilon = \varepsilon^{M} n, \tag{7.4}$$

ε^{M} is the market elasticity of demand, and n is the number of firms in the industry. This hypothesis is not used in the G.E.T. model for a couple of reasons, the most important of which is there is no reason to presume given the level of aggregation used that all firms are selling perfect substitutes. An alternative assumption is referred to as the symmetric substitutes assumption with CES commodity aggregators; this is also referred to as the Spence model of monopolistic competition.[25] The basic economic idea is that an industry consists of some number of firms each of whom are producing similar goods, but each of which has an identical cross price elasticity of demand with each other good in the commodity group. Call this cross price elasticity γ, a positive number. This assumption can be rationalized by the observation that the demand for the commodity group as a whole is given by a commodity aggregator

$$Q = \Sigma\left(q_i^{\beta}\right)^{1/\beta} \qquad \beta = 1-\left(\frac{1}{\sigma}\right) \qquad \text{and} \qquad \sigma > 1.0 \tag{7.5}$$

where Q is the commodity aggregate, the q_i are the individual components corresponding to each firm's individual product and σ is elasticity of substitution between all pairs of commodities. One feature of this analytical structure is that if each firm takes the *prices* of all other firms as given, and assumes its own market share is not large, $-\sigma$ is the constant individual firm price elasticity of demand; furthermore this holds independent of the number of firms in the commodity group. The constant α in the firm's perceived demand function is given by

$$\alpha = Y \Big/ \left(\Sigma\, p_i^{1-\sigma}\right) \tag{7.6}$$

where Y is total expenditure on the commodity group and p_i are individual firm prices.

This theory, which is quite clean in a partial equilibrium framework without intermediate goods, becomes significantly complicated within a general equilibrium framework including intermediate goods in production and demand. From the applied G.E. perspective the central questions are two-fold: (a) calculating a general equilibrium demand function; and (b) going from a market demand to an individual firm's perceived demand function. With respect to (a) there are inevitable and difficult complications regarding individual market participants' knowledge of the general equilibrium structure of the economy. The assumption employed within GET follows Negishi (1961) in assuming that firms have local knowledge of the market elasticity of demand for the product group within which they sell. Locally this elasticity is given by taking share weighted market elasticities of export, final and intermediate demand. More precisely we have that the market elasticity of demand in commodity i is given by

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[25] See Spence (1976).

$$\varepsilon_i^M = \varepsilon_i^d \frac{D_i^c}{X_i} + \varepsilon_i^{xu} \frac{E_i^u}{X_i} + \varepsilon_i^{xr} \frac{E_i^r}{X_i} + \sum_{j \in M} \frac{a_{ji} X_j}{X_i} \varepsilon_{ij}^m \tag{7.7}$$

The important characteristic of this formula is that the implicit assumption is made that in calculating intermediate demand elasticities, total output of the demanding industry is held constant; that is the ε_{ij}^m are substitution elasticities only. From a general equilibrium perspective one can imagine a more complicated theory where individual firms take account of the induced output response of downstream industries due to lower prices on their intermediate inputs. While it is possible to operationalize such a theory, the computational burdens are significant, and at this stage do not seem to warrant the required effort. In the formulae (7.7) each of the individual component elasticities is given in terms of underlying structural parameters by the following equations.

Final demand elasticity:

$$\varepsilon_i^d = -\sigma_i + \left[\frac{p_i^c D_i^c}{p_i^c D_i^c + p_i^u D_i^u + p_i^r D_i^r} \right] (\sigma_i - 1) \tag{7.8}$$

Export demand elasticity :

$$\varepsilon_i^{xu} = - \sigma_i^u - \left(1 - \sigma_i^u\right) \frac{q_{iu}^c \, E_i^u}{I_i^u} \tag{7.9}$$

$$\varepsilon_i^{xr} = - \sigma_i^r - \left(1 - \sigma_i^r\right) \frac{q_{ir}^c E_i^r}{I_i^r} \tag{7.10}$$

Intermediate goods demand elasticity for product i in industry j:[26]

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[26] $\hat{\sigma}_{ij}$ is the perceived elasticity of substitution between alternative intermediate inputs. In the long run version of G.E.T. the actual intermediate input aggregator is Cobb-Douglas so $\hat{\sigma}_{ij}$ equals unity for all i and j. In the Keynesian version of G.E.T. a CES aggregator is used so the actual σ_{ij} are given by the appropriate structural parameter. In the case of the long run model $\hat{\sigma}_{ij}$ are set equal to a constant which is greater than unity. In this case the assumption implies that in the eyes of users, foreign and domestic inputs are more substitutable than a Cobb-Douglas assumption actually allows. In future implementations a full Armington-CES treatment of

$$\varepsilon^{m}_{ij} = -\hat{\sigma}_{ij} + \hat{\sigma}_{ij}\left(\frac{\alpha_{ij}\beta_{ij}}{\nu_j} - 1\right) \tag{7.11}$$

Having derived the market elasticity of demand, the next step is deriving the individual firm's perceived elasticity of demand. The basic problem is to keep the theory operational while at the same time using the insights of imperfect competition pricing theory. For our purposes one of the significant drawbacks of the pure Spence-Chamberlin symmetric substitutes pricing model under Nash price conjectures is that the market elasticity of demand plays no important role in determining the individual firm's pricing rule; the entire emphasis is placed on the CES aggregator elasticity. As this elasticity is not equal to the traditional market price elasticities it lacks considerable empirical appeal. Therefore an alternative route was chosen which explicitly focuses on the role of the market elasticity of demand as a determinant of individual firm pricing. The assumption made is that an individual firm views its own demand as proportional to market demand; an alternative way of expressing this is that firms assume their market share is constant. Underlying this assumption (which does require that individual firm's produce perfect substitutes) is the notion that all firms in the industry will follow more or less similar pricing rules.[27] The main criticism of this assumption is that it assumes an implicit degree of collusion which might seem excessive if the rule is taken literally. As will be seen however the rule is modified somewhat in its implementation.

2.7.3 Mixed Pricing Rules in Import Competing Industries

Within G.E.T. for those industries which are clearly not primarily export industries a form of mixed pricing rule is used. The mixture in this case is over the pure forms of Eastman-Stykolt pricing, and the MCH pricing rule. We start with the pure markups under either ESH or MCH.

MCH markup of producer prices over unit cost, Δ^{M}_{i}

$$\Delta^{M}_{i} = \frac{-\varepsilon^{M}_{i}}{(-\varepsilon^{M}_{i} - .1)(1 + \theta^{o}_{i})} \tag{7.12}$$

Eastman-Stykolt gross markup of producer prices over unit costs, Δ^{ES}_{i}

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intermediate inputs will be implemented in both the long run and Keynesian versions of the model.

[27] Formally this assumption is equivalent to a partial equilibrium oligopoly model in which the following assumptions are maintained: 1) all firms are identical; 2) the number of firms is fixed; 3) product is homogeneous; and 4) each firm expects all other firms to match any price increase or decrease.

$$\Delta_i^{ES} = \frac{(1 + \phi_{ic}^{u})b_i^{u}}{v_i} \tag{7.13}$$

The two markups are averaged with a weighting factor of λ_i on the ESH markup. The actual markup used in the empirical implementation of the model is

$$\Delta_i^{\lambda} = cv_i\left[\lambda_i\Delta_i^{ES} + (1-\lambda_i)\Delta_i^{M}\right] \tag{7.14}$$

where cv_i is referred to as the *conjectural variation coefficient* for industry i. The interpretation of this coefficient is that of a structural constant for a particular industry reflecting different patterns of behaviour, and insensitive to changes in policy variables. On the other hand the weight λ_i reflects the relative importance of Eastman-Stykolt effects, or as Hazeldine (1981) refers to it, as the importance of the 'Law of One Price'. λ_i is determined empirically in the implementation of G.E.T. As λ_i tends to unity prices within an industry are determined by foreign competing prices. On the other hand as λ_i tends to zero prices are set largely by demand elasticities in the market as a whole, including domestic demand elasticities. Note that even under MCH the export elasticity of demand plays some role in the determination of domestic price markups. Under ESH however domestic prices are actually determined in the foreign market. This is an important distinction to bear in mind when interpreting the results of the model for extreme values of λ_i.

The conjectural variation coefficient cv is determined in the benchmarking procedure, such as to bring observed price cost margins into line with theoretically determined price-cost margins. This will be discussed at greater length in the chapter 5 on calibration procedures.

2.7.4 Export Industries and Contestable Market Pricing

A number of Canadian industries are distinguished by the characteristic that they produce an extremely large share of total output for export, are not import competing (and hence not protected), and might be distinguished by product characteristics which tend to put them at the end of the standardized product spectrum. Within such industries, which will be referred to simply as export industries, ignoring the complications of two-way trade, both ESH and MCH pricing seem inappropriate. The free/entry exit assumption is deemed inappropriate because either actual or potential price competition forces firms to price at average cost; as profits are always zero there is no reason for entry to occur. In the GET model we adopt the market structure assumption that such industries are 'long run contestable' industries. In the context of trade the theory underlying this type of market structure is laid out in chapter 4 of Helpman and Krugman (1985). The two basic assumptions underlying this market structure are a) there is no exit or entry so that the number of firms are held constant, and b) prices are set such as to equal average cost. The addition of these contestable export industries to the basic structure is a significant change from the old GET model so that it is worth elaborating in some detail what is involved. With a fixed number of firms and average cost pricing changes in the scale of industry output have a one-to-one correspondence with the change in the scale of individual firm outputs. Thus increases in industry output imply, at constant input prices, a fall in the average cost of production and hence in the selling price of output. In industries such as these there is nothing identifiable as 'rationalization'; scale changes merely reflect changes in either input costs or shifts in demand (usually external demand). The major theoretical problem with such a model of market structure is the apparent non-effect of foreign prices on the industry. For example a cut in foreign tariffs only impacts on the industry to the extent that it shifts the demand curve of the industry; there is no direct mechanism by which domestic selling prices are affected. As there is some evidence that in export markets of small countries world prices play an important role in explaining prices the contestable market model should be treated with some caution. An alternative model with prices set at least in part in the foreign market may be more appropriate. This will be discussed later in section 2.7.5 'Export Price Discrimination'.

Formally average cost markups are determined simply as an identity by

$$\Delta_i^B = AC_i / \left(v_i\left(1 + \theta_i^0\right)\right) \tag{7.15}$$

2.7.5 Export Price Discrimination

It has been argued that in industries characterized by product differentiation price discrimination between different national markets is common, given the absence of an effective means for arbitrage. Broadly, there are two factors in setting the price in any market; costs of production and the structure of demand and competition. While it may be desirable to consider a complete theory of profit maximizing price discrimination by exporters, given the absence of detail in GET regarding market structure in foreign markets, it is not feasible in the current model. A somewhat ad hoc approach to the export pricing equation is adopted, but one that lends itself to empirical implementation.

To keep notation to a minimum the discussion will refer only to the U.S. export market, and commodity detail will be ignored. The Canadian exports to the U.S. is price of p_u^x, but the consumer price after the U.S. tariff is imposed is $q_u^c = \left(1+\phi_u^c\right)p_u^x$. A competitive theory of export pricing would be Canadian exporters simply match the price of the competing product in the U.S., q_u^u. Hence the export price p_u^x would be set, such that[28]

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[28] (7.16) would have to be amended suitably if there were an export subsidy on exports to the U.S.

$$p^x_u = q^u_u / \left(1 + \phi^c_u\right). \tag{7.16}$$

Alternatively, export prices could be set to reflect cost conditions in the Home country. Given that producer prices in the home market are markups on cost, a simple non-discriminatory cost based export pricing rule is to set export prices equal to domestic producer prices.

$$p^x_u = P^c \tag{7.17}$$

Under MCH export pricing is non-discriminatory, but the optimal P^c reflects in part the export share of total sales, and the elasticity of export demand. Under the pricing rule (7.16) a reduction in the U.S. tariff leads to an immediate increase in the export selling price, thus improving the terms-of-trade. Under non-discriminatory export pricing a reduction in the U.S. tariff has no impact effect on domestic costs, and hence the first-round effect is to raise the volume of exports.

A mixed pricing rule which reflects both sets of considerations is

$$p^x_u = \delta^x q^u_u / \left(1 + \phi^c_u\right) + \left(1 - \delta^x\right) P^c \tag{7.18}$$

For $\delta^x = 0$, the usual non-discriminatory pricing rule is recovered, and for $\delta^x = 1$ we get competitive export pricing. The export pricing rule (7.18) is straightforward to implement within GET. For different industries empirical estimates of δ^x can be used reflecting industry specific considerations. Provided industry revenues are defined as in (5.3) the model discussed thus far is simply a special case of (7.18) with $\delta^x = 0$.

2.8 Entry/Exit and Long-run Equilibrium

This section provides the detail on long run equilibrium conditions at both the industry and general equilibrium level. These are, in a fundamental sense, the *last* and final equilibrium conditions of the model.

As noted previously any quasi-equilibrium has the feature that economic profits and losses are non-negative. A fundamental characteristic of long run equilibrium should be that all economic profits are zero, or alternatively that capital earn the economy wide rate of return no matter where it is located, which in turn equals the world rate of return on capital. In the tradition of Marshallian economics this process is arrived at by having firms enter those industries, in which economic profits exist, and exit from those industries in which economic profits are negative. The exact dynamics of this process of this entry/exit process are not detailed within GET, but the long run equilibrium has the characteristic that the number of firms, ν_i, in each of the A and B industry groups is such that jointly with the target markups implied by the appropriate pricing theory, actual equilibrium profits are zero.

Thus we have the following definition:

A *Long run equilibrium* is a *quasi-equilibrium* with the additional characteristics that

(1) Actual markups equal target markups, as determined by the appropriate pricing theory

and (2) economic profits are zero in all industries.

This equilibrium concept is the natural analogue of a flexible price full employment equilibrium of neoclassical economics, extended to an imperfectly competitive environment with trade. It is very close in spirit to the equilibrium of Chamberlin (1956) in his treatment of monopolistic competition, and the general equilibrium treatment of imperfectly competitive firms used by Negishi (1960). The industrial structure variables $\mathcal{J}=(\Delta,\nu)$ are the variables that are determined along with prices, and outputs in a long run equilibrium. Industrial structure is thus *endogenously* determined in the long run equilibrium of GET. In doing comparative static analysis of the model it is important that the change in industrial structure induced by a change in an exogenous variable is predicated on the assumption that the pricing/entry/exit assumption of the basic long run equilibrium model are valid both before and after the change in the exogenous variable. It is possible to imagine some changes in exogenous variables, in which the initial assumptions may no longer be appropriate. An example would be a very substantial increase in a domestic tariff on a marginally export oriented industry. Initially contestable pricing might be the appropriate assumption, but economic theory and evidence would suggest that after the tariff increase, the high rate of protection might make ESH pricing a more appropriate assumption. Some judgment must be exercised in conducting comparative static analysis within the GET model, given assumptions about the basic determinants of industrial structure.

A couple of comments are in order on some technical matters. First, there remains a considerable debate within economics as to the appropriate equilibrium concept under imperfect competition. Much of this debate has to do with the expectations of firms as to rivals' behaviour, and the exact nature of the firm's belief about the demand curve they face. Arbitrary assumptions about beliefs in this regard lead quite quickly to multiple or ill-defined equilibrium.[29] Within the GET model assumptions about conduct in imperfectly competitive industries is implicitly contained within the pricing models adopted. The pricing models adopted tend to be ad hoc in that they attribute profit maximization as the principal objective of the firm in setting prices, but the details of the informational and strategic environment in which firms compete, including the description of entry and exit is less than complete. For example, under MCH pricing information about the general equilibrium demand curve is reduced to a summary statistic on the local elasticity of the firm's demand curve under certain hypotheses. Under ESH pricing the exact nature of the collusive equilibrium is not spelled out. Ultimately these pricing models then must be viewed as plausible *empirical* descriptions of industry conduct. Within a large scale general equilibrium model it is simply not possible to model in great detail the game theoretic strategic interaction of all firms. This is not an apology, but simply a statement as to what these models are about.

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[29] See Hart (1979) and Novshek and Sonnenschein (1978) for a discussion of this point.

Another technical point concerns the uniqueness of equilibrium. It is well known that in GE models equilibrium may not be unique. In undertaking policy counterfactual analysis there is the hope that either the equilibrium is unique, in which case comparative static analysis is clearly valid, or that at least local uniqueness of equilibrium holds, and thus small changes in policy or other exogenous parameters, will not result in 'jumping' from one equilibrium to another. For most AGE models the uniqueness question is addressed by using different start points for the solution algorithm and checking that the algorithm always converges to the same final equilibrium value. Similar checks are done on the GET model, but it must admitted that theoretically there is nothing to preclude the existence of multiple equilibrium.[30]

Comparative static analysis is done by comparing different long run equilibrium corresponding to different sets of exogenous variables. In reporting these comparative static changes in various index numbers it important for the AGE analyst to stress to users of the results the appropriate interpretation on the results. Comparative static results are not forecasts; they do not occur in real economic time like a macroeconomic forecasting model. For a given change in the exogenous variables, the change in the endogenous variables tell what the model equilibrium would have been under the same long run structural circumstances, if the exogenous variables were other than they had been. The emphasis on the *counterfactual* nature of AGE results is most important if model results are not to be misinterpreted.

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[30] Readers familiar with GE analysis might object that with the assumption of a single representative agent, it might appear that the well known Weak Axiom assumption will be satisfied and thus the equilibrium is assured of being unique. Arrow and Hahn (1971), chapter. 9 discuss this case in detail. While this version of GET employs the representative agent assumption on the Home country it must first be recognized that with three regions, there is no assurance that tastes in all three regions are both identical and quasi-homothetic, thus satisfying the Weak Axiom assumption in aggregate. Even more problematic however is the role of imperfect competition. It is possible for example in a pure MCH partial equilibrium model of the Chamberlin sort that multiple equilibrium can exist given that the demand curve for the industry is sufficiently 'peculiar', even though it remains downward sloping. A case like this has been explored in an AGE model by Harris and McDonough (1987).

Appendix to Chapter 2

This appendix will demonstrate that external balance is determined residually given commodity and labour market clearing. For expositional purposes we use a simplified two region model (Canada-Foreign), with tariffs the only ad valorem distortion, and set VXFS, the value of exogenous final supply, equal to 0. Start with income equal to the expenditure condition.

$$\Sigma_{i\epsilon\mathcal{M}}\ P_i^c D_i^c + P_i^f D_i^f = I^c \tag{A.1}$$

$$\equiv w\bar{L} + \text{DKY} + \psi\ \text{AGPROF} + \text{BOP} + \text{GOV}$$

For each sector j with zero profits we write the revenue equal cost condition,

$$w\bar{L} + \Sigma r_j K_j = \sum_j P_j X_j - \sum_i \sum_j P_i YY_{ij} - \sum_i \sum_j P_i^f YY_{ij}^f \tag{A.2}$$

Substitute (A.2) into (A.1) to yield

$$\begin{aligned}\Sigma_i P_i^c D_i^c + P_i^f D_i^f = \sum_j P_j X_j - \sum_i \sum_j P_i YY_{ij} = \Sigma\ P_i^f YY_{ij}^f - \sum_j r_j K_j \\ + \text{DKY} + \text{BOP} + \text{GOV}\end{aligned} \tag{A.3}$$

where

$$\text{GOV} \equiv \sum_i T_i D_i^f + \sum_i \sum_i T_i YY_{ij}^f \qquad \text{(lump-sum transfer)} \tag{A.4}$$

$$\text{VKM} \equiv \Sigma\ r_j K_j - \text{DKY} \qquad \text{net capital service imports}$$

T_i: unit tariff on good i.

Let $P_i^c = P_i$, and $P_i^f = Q_i + T_i$. Then re-writing (A.1) and substituting (A.2) into (A.3) gives

$$\begin{aligned}\Sigma\ P_i D_i^c + P_i^f D_i^f = \sum_j P_j X_j - \sum_i \sum_j P_i YY_{ij} - \sum_i \sum_j P_i^f YY_{ij}^f \\ - \text{VKM} + \text{BOP} \\ + \sum_i \left(P_i^f - Q_i\right) D_i^f + \sum_i \sum_j \left(P_i^f - Q_i\right) YY_{ij}^f\end{aligned} \tag{A.5}$$

Re-writing (A.5) as

$$\sum_i P_i\left(X_i - D_i^c - \sum_k YY_{ik}\right) - \sum_i P_i^f\left(D_i^f + \sum_k YY_{ik}^f\right)$$

$$= VKM + BOP + \sum_i T_i D_i^f + \sum_i \sum_j T_i YY_{ij}^f$$

and using the output identities,

$$E_i \equiv X_i - D_i^c - \sum_k YY_{ik}$$

$$M_i \equiv D_i^f + \sum_k YY_{ik}^f$$

gives,

$$\sum_i P_i E_i - \sum_i Q_i M_i - \sum T_i M_i - VKM + BOP + \sum_i T_i M_i = 0 \qquad \text{(A.6)}$$

or

$$\boxed{\sum_i P_i E_i - \sum_i Q_i M_i - VKM = -BOP} \qquad \text{(A.7)}$$

That is *trade surplus - net capital imports = Current Account Deficit*. Hence if BOP = 0, external balance is determined as the residual equation by Walras Law. Note if value of exogenous final supply $\neq 0$, then it is necessary to amend the definition of exports to

$$E_i = X_i + FS_i - D_i^c - \sum_k Y_{ik}$$

where X_i now interpreted as total *produced* output of commodity i.

In the event that economic profits are not zero (A.7) is amended to

$$\sum_i P_i E_i - \sum_i Q_i M_i - VKM - (1-\psi)AGPROF = - BOP \qquad \text{(A.7')}$$

$(1-\psi)$AGPROF represents income paid to foreigners as a consequence of owning a share, $(1-\psi)$, of domestic industry. AGPROF is aggregate quasi-rents and defined by

$$AGPROF = \sum_j P_j X_j - \sum_i \sum_j P_i YY_{ij} - \sum_i \sum_j P_i^f YY_{ij}^f - w\bar{L} - \sum_j r_j K_j \qquad \text{(A.8)}$$

and if all taxes and subsidies are included then P_j should be replaced by P_j^x where

$$P_j^x = P_j^c\left(1+\tau^x\right)\left(1-\theta^x\right)$$

Chapter 3

Reporting Simulation Output

3.1 Introduction

This chapter provides some details on the output of the GET model. Much of the output is provided in the form of economic index numbers derived from the underlying model's microeconomic numbers. Due to the relatively large size of the empirical model it is important to have a thorough understanding of the basic indexes which are reported. Whenever possible a conventional economic index is calculated in a manner consistent with standard practice. In these cases, the details of the index number are not reported in this section. In other cases while the basic concept is familiar the details of the index are not, and in these cases some discussion is provided.

In reporting model results, it invariably the case that the results of the model are measured against some reference case. In most applications of GET the reference situation is the base equilibrium, although this will not always be true.[31] In this section attention will be restricted to a comparison of one set of equilibrium results with another set of equilibrium results. The reference, or control, or benchmark equilibrium, will be denoted by the pre-superscript o. The comparison equilibrium will be denoted by the pre-superscript 1. An index comparing equilibrium ${}^{0}x$ with equilibrium ${}^{1}x$, is a function $I({}^{0}x, {}^{1}x)$.

In other circumstances the index itself is simply an aggregator function, aggregating disaggregated microeconomic data into a more easily interpretable, or manageable, aggregate number. It is also important to distinguish between those situations in which bilateral comparisons are being made, between the base equilibrium and an alternative equilibrium for example, and those situations in which multilateral comparisons are made. In applications of GET it will often be the case that alternative policies will be evaluated against the base case. In these case it would be desirable if the indexes used were legitimate multilateral indexes.[32]

3.2 Indexes of Real Income

One of the principal purposes of the GET model is to measure deadweight gains and losses from policy changes relative to the reference equilibrium. The case of a domestic tariff cut will be discussed in some detail to provide an illustration of some central concepts. The merits and demerits of alternative measures of deadweight burden are not taken up here. A recent survey is found in Boadway and Bruce (1984), chapters 2 and 3.

The central figure in the analysis is the domestic consumer; national welfare is thought of as coincident with the well being of the national consumer, and the interest is in measuring the 'real utility' gains and losses to the consumer from policy induced or other changes.

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[31] In chapter 5, section 4 details of the base equilibrium against which policy counterfactuals are carried out is provided.

[32] A basic reference on index numbers the reader may find useful is Diewert (1987). He makes the important distinction between bilateral comparisons and multilateral comparisons.

A standard measure of welfare change, without specific reference to consumer tastes is the index of real *Gross National Expenditure*, or real GNE. Real GNE is nominal GNE deflated by a Laspeyres price index of the cost of living, reflecting changes in the prices of both imported and domestically produced commodities. Nominal GNE in the model is simply I^c of chapter 2 in the relevant situation. Hence the increase in real GNE in situation 1 relative to the base situation 0 is defined as

$$\mathrm{IGNE} = \left[({}^1I^c / {}^0I^c) \times \frac{\sum_{i \in \mathcal{G}} {}^0P_i^c \, {}^0D_i^c + {}^0P_i^u \, {}^0D_i^{cu} + {}^0P_i^r \, {}^0D_i^r}{\sum_{i \in \mathcal{G}} {}^1P_i^c \, {}^0D_i^c + {}^1P_i^u \, {}^0D_i^{cu} + {}^1P_i^r \, {}^0D_i^r} \right] \tag{2.1}$$

In defining more exact welfare indicators it is convenient to start with the expenditure function describing the national consumers tastes. This is denoted by

$$E(\mathcal{P}, U) = I^c. \tag{2.2}$$

U denotes the utility level of the consumer given prices $\mathcal{P}$ and income I^c. In the situation in which the preferences are homothetic, and normalized so that the utility function is linear homogeneous, as in the case of the GET model, the expenditure function decomposes as

$$E(P, U) = e(\mathcal{P})U \tag{2.3}$$

where $e(\circ)$ is referred to as a 'true price index' or *true cost of living function*. A common dollar measure, or money metric of welfare change from situation 0 to situation 1 is the *Hick's Equivalent Variation*, or EV, defined as

$$EV({}^1\mathcal{P}, {}^1U; {}^0\mathcal{P}, {}^0U) = E({}^0\mathcal{P}, {}^1U) - E({}^0\mathcal{P}, {}^0U). \tag{2.4}$$

Using (2.3) the EV can be expressed as

$$EV = e({}^0P)({}^1U - {}^0U). \tag{2.5}$$

Rather than reporting this number as an absolute it is more common to report it as a percentage of base expenditure. Thus we define the welfare gain or loss as

$$WELF = EV / {}^0I^c = ({}^1U - {}^0U)/{}^0U. \tag{2.6}$$

The last decomposition is valid only under the homogeneous preference assumption. Some authors report the Hicks Compensating variation as well as the equivalent variation.[33] In the case of arbitrary preferences there will be a difference in the real income measure reported either in percentage or absolute form. In the case of homogeneous preferences however the welfare measure reported as a percentage of base expenditure is the same using either the Compensating Variation or the Equivalent Variation. For simplicity we report only the equivalent variation, although it should be kept in mind that the same numbers when reported in percentage form could also interpreted as the Compensating Variation measure of welfare change.

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[33] See Whalley (1986) for example.

In the context of trade liberalization issues, it is common following Johnson (1960) to decompose the aggregate real income gain into consumption and production gains. The decomposition which is easily interpretable in a homogeneous good, small open economy model, is not as straightforward in the Armington style model with differentiated goods. It is useful to begin by defining the consumption cost of the tariff. Intuitively the consumption cost of domestic tariff protection exists because the higher prices on imported goods implies that consumers at initial income levels are worse off. The consumption cost attempts to measure how worse off. Formally the consumption gain of situation 1 over situation 0 is defined as

$$\mathrm{CON} = {}^1\mathcal{P}\circ{}^0D - E({}^1\mathcal{P},U^0) \tag{2.7}$$

where the first term is the cost of purchasing the consumption bundle of the 0 situation, at prices prevailing in the 1 situation. Another, and perhaps more intuitive interpretation is to note that with unchanged production between situations and exogenous import prices the consumption bundle ${}^0D$ is a feasible purchase at world prices ${}^1\mathcal{P}$ in the initial equilibrium. Therefore holding production unchanged it would be possible through trade to achieve the same level of real income as in the base equilibrium by consuming at prices ${}^1\mathcal{P}$, but with CON$ less income. This is the rationale for referring to (2.7) as the consumption cost of protection.

A central feature of the model is that factor prices are endogenous. For this reason we will often report changes in the 'real' value of the supply wage in the economy. Noting that aggregate labour supply is inelastic, this can then be interpreted as the change in the *real* income of labour. The appropriate deflator for the nominal wage is the true cost of living index given wage earner preferences. All wage earners are assumed to have the same preferences as given by the aggregate utility function. In this case the true cost of living index of situation 1 relative to situation 0 is given by

$$\mathrm{COLA} = e({}^1\mathcal{P}) / e({}^0\mathcal{P}) \tag{2.8}$$

The *percentage* increase in the real wage is therefore given by

$$\hat{W} = \left[\frac{{}^1W}{{}^0W\ \mathrm{COLA}} - 1.0 \right] \times 100 \tag{2.9}$$

The increase in the real wage reflects *both* consumption and production gains. Practically speaking given a zero economic profit condition it is the most important change in real income sources within the model.

3.3 Aggregate Production Indexes

The *national production gain* (NPG) is defined residually as the real income gain not attributable to consumption gains;

$$\mathrm{NPG} = \mathrm{EV} - \mathrm{CON}. \tag{3.1}$$

In the small open economy case it can be shown that the production gain in the context of given technology and aggregate factor supplies is the increase in the value of production, valued at world prices. In the presence of scale economies, and mobile capital the aggregate production possibilities set actually shifts in moving from one situation to another. Thus a change in policy variables (tariffs for example) causes a movement both along the frontier, as well as a shift in the frontier. Furthermore under the Armington assumption there are changes in the terms of trade, favourable or unfavourable which also affect the welfare gains in moving from situation 1 to situation 0. For both reasons the residual method of defining production gains is less than satisfactory.

From the production standpoint it would be useful to have a measure like real GDP which attempts to measure the shift in the production possibilities set of the economy; this would incorporate both changes in the efficiency of production, perhaps due to scale changes, or efficiency gains in resource allocation, as well as the increase in the factors of production used. A problem with using a conventional real GDP number for this purpose is that there is a bias implicit in using internal prices, pre-tariff reduction, in reporting the change in the value of production. In figure 3.1, the tariff and free trade equilibrium in the standard 2-good small open economy are depicted. The line AA' represents base GDP in the presence of the tariff. The line BB' represents GDP valued at base prices at the free trade equilibrium. In this case free trade real GDP line must lie below the base equilibrium line. At world prices the value of GDP is given by the line PP', and clearly GDP valued at these prices is maximized at the free trade point F. In designing an index of real production, it is important to eliminate this particular bias from the index. Johnson's production gain was in fact the increase in GDP valued at world prices. For similar reasons we define an alternative index of aggregate production gain, always using the post-policy change prices, rather than the base prices. To this end we first define adjusted base GDP (GDPB) as

$$\text{GDPB} = \sum_{i\in\mathcal{M}} \left\{ \left(1+\theta_i^o\right) {}^1P_i \, {}^cX_i - \sum_{j\in\mathcal{C}} {}^1s_{ij}^c YY_{ij}^c + {}^1s_{ij}^u YY_{ij}^u + {}^1s_{ij}^u YY_{ij}^r \right\} \quad (3.2)$$

GDPB is just GDP in the base situation valued at final situation prices. Letting ^{1}GDP denote GDP at current prices in situation 1, then the *aggregate production gain* (APG) of situation 1 over situation 0 is defined as

$$\text{APG} = \frac{{}^1\text{GDP} - \text{GDPB}}{\text{GDPB}} . \quad (3.2)$$

It is important to remember than in the case of a policy change that leads to an inflow of capital, the APG will generally increase in response to that inflow; likewise for outflows.

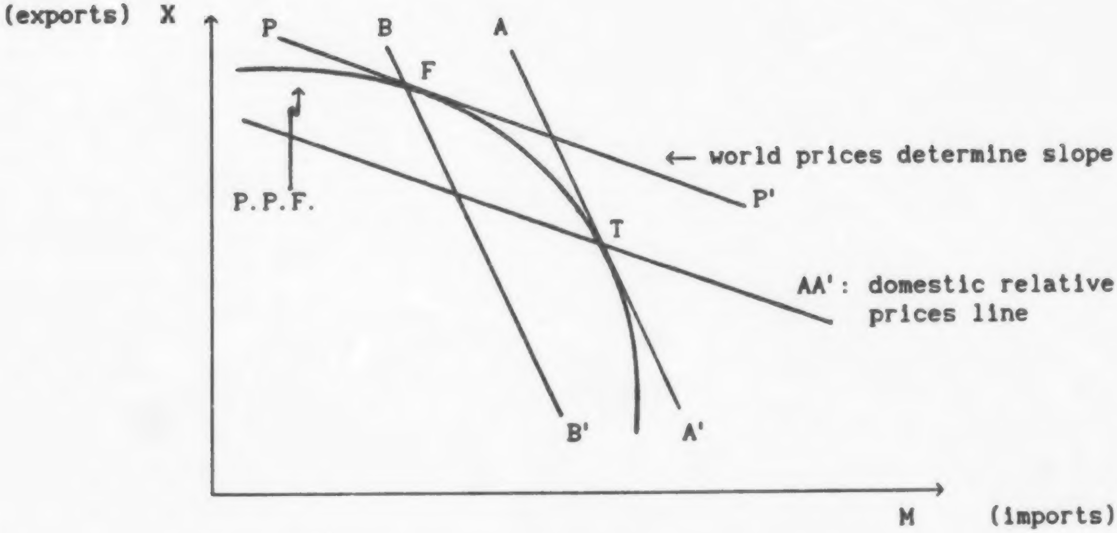
(exports) X
P
B
A
F
P.P.F.
← world prices determine slope
P'
T
AA': domestic relative prices line
B'
A'
M
(imports)

Figure 3.1

Bias in Real GDP Calculations Due to a Tariff Cut

3.4 Industry Productivity Indexes

In addition to reporting aggregate production and welfare indexes the GET model focuses on individual industry performance. To this end results on productivity and efficiency are reported. For the most part complex productivity indexes are avoided to keep the presentation as simple as possible and to conform with reporting practices of national statistical agencies.

In the base equilibrium factor shares by industry have values[34]

$$\alpha^{o}_{ij},\ \beta^{co}_{ij},\ \beta^{uo}_{ij},\ \beta^{ro}_{ij},\ \alpha^{o}_{nj},\ \alpha^{o}_{kj}, \tag{4.1}$$

In the strict Cobb-Douglas constant returns industries model these shares are constant across simulations and are read in from the calibration program. In the A and B industries however the factor shares are understood to be total factor shares covering both fixed and variable costs. As the ratio between fixed and variable costs shifts it would be expected that these shares would change. In addition output weights for each equilibrium are computed (ex post)

$$\text{(Output weights)} \qquad w^{x}_{i} = \frac{X_i}{\Sigma_{i\varepsilon M} X_i} \tag{4.2}$$

with $\Sigma_{i\varepsilon M} w^{x}_{i} = 1.0$. In looking at aggregates of individual productivity indexes it was decided to use output weighting, rather than value-added weighting. Clearly both methods are feasible and could be used when necessary. The first index on a levels basis is simply the output per person hour,

$$\text{(industry)} \quad h_j = X_j/L_j, \text{ and } \qquad \text{(aggregate)} \quad H = \sum_{i\varepsilon M} w^{x}_{i}\, h_i$$

A labour productivity index (percent increase in output per person hour of situation-1 over situation-0) is computed as

$$LP_j = \left(\frac{{}^{1}h_j}{{}^{o}h_j} - 1 \right) \times 100 \tag{4.3}$$

and in aggregate as

$$LP_A = \left(\frac{{}^{1}H}{{}^{o}H} - 1 \right) \times 100. \tag{4.4}$$

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[34] In equation (4.1) the notation follows that of chapter 2 on production shares, with the exception that in the A and B industries the shares in (4.1) are to be interpreted as inclusive of fixed cost factors in the case of capital and labour.

The output weighting will affect this index due to compositional shifts across industries. Hence it is possible that individual productivity indexes would show no improvement, but aggregate productivity would rise because of a shift in total output produced toward higher productivity sectors.

In addition to labour productivity, a total factor productivity index, or Divisia index,[35] a ratio of geometric input quantity indexes, is computed. The economic intuition is to assume (falsely) that output is produced by a Cobb-Douglas production function, with constant share coefficients, but possibly shifting efficiency parameter. The total factor productivity index measures the change in the pure efficiency parameter of the Cobb-Douglas functional form. It should be noted that the significance of the 'as if' hypothesis in this index. For industries with scale economies the industry production function is not even well defined, given shifting numbers of firms, and decreasing costs. Thus the index reports a shift in the efficiency of use of all factors; this shift in efficiency may be caused by an increase in scale efficiency, as well as composition shifts, for example from low productivity to high productivity sectors.

In defining total factor productivity, first define the factor productivity coefficient by industry,

$$\begin{aligned}\mathrm{Prod}_j = \exp\Big\{&\log X_j - \Sigma_{j\varepsilon C}\, \alpha^o_{ij}\beta^{co}_{ij} \log Y^c_{ij} + \alpha^o_{ij}\beta^{uo}_{ij} \log Y^u_{ij} \\ &+ \alpha^o_{ij}\beta^{ro}_{ij} \log Y^n_{ij} - \alpha^o_{nj} \log L_j - \alpha^o_{kj} \log K_j\Big\}\end{aligned} \tag{4.5}$$

These are output weighted to give an aggregate total factor productivity coefficient

$$\mathrm{AProd} = \Sigma_{i\varepsilon M}\, w^x_i\, \mathrm{Prod}_j\ . \tag{4.6}$$

Total factor productivity indexes are defined as

$$\text{(industry)}\quad \mathrm{Tfact}_j = \left(\frac{{}^1\mathrm{Prod}_j}{{}^o\mathrm{Prod}_j} - 1\right) \times 100 \tag{4.7}$$

$$\text{(aggregate)}\quad \mathrm{Atfact} = \left(\frac{{}^1\mathrm{Aprod}}{{}^o\mathrm{Aprod}} - 1\right) \times 100. \tag{4.8}$$

3.5 Cost Efficiency and Rationalization Measures

Partial equilibrium and aggregates across industries of various cost efficiency indexes are reported. These indexes are more in the tradition of industrial organization studies, and focus on the cost curve of individual firms, and the division of output across firms. Industry rationalization is an important part of the endogenous response within GET, and thus measures of how industry structure change are quite interesting.

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[35] Diewert (1987) contains a review and summary of various productivity indexes used.

The first index is the cost elasticity. In the general case the elasticity of the total cost function with respect to total output is given by

$$\varepsilon_i^{\text{cost}} = \frac{C'_i(y_i)y_i}{C_i(y_i)} \qquad (5.1)$$

given a cost function $C_i(y)$, defined on output level y_i. Given the cost function (4.5) of chapter 2 the cost elasticity can be written as

$$\varepsilon_i^{\text{cost}} = \frac{v_i}{AC_i(y_i)} \qquad (5.2)$$

With an everywhere declining average cost function as in the case of the HBCF the cost elasticity is always less than 1.0, but increasing uniformly from 0 to 1.0 as output tends to +∞. The cost elasticity is best interpreted as a measure of unexploited scale economies; locally it reports how costs rise with a one percent increase in total output. In the case of the HBCF the local cost elasticity (5.2) actually gives a measure of *global* unexploited scale economies relative to the output at which the elasticity is calculated. This follows as $v_i = \inf_{y>0} AC_i(y)$. For cost functions other than the HBCF this global interpretation is *not valid*.

Another simple measure of cost efficiency is the spreading out effect on fixed costs as output increases within the firm. Given that variable costs do not rise this is of particular importance. Hence levels of average fixed costs are

$$\text{(industry)} \quad \text{fix}_j = \frac{\widehat{FC}_j}{X_j} \qquad \text{(aggregate)} \quad \text{FIX} = \Sigma_{j\varepsilon N}\, w_j^x\, \text{fix}_j \qquad (5.3)$$

$$\widehat{FC}_j = \nu_j\left(\bar{w}_j\, \omega_{nj} + \bar{r}_j\, \omega_{kj}\right).$$

Note that fixed costs across equilibrium must be computed at a constant set of factor prices. In practice either base or final prices can be used. For multilateral comparisons base prices are recommended.

$$\text{Ifix} = \left(\frac{{}^1\text{fix}}{{}^0\text{fix}} - 1\right) \times 100 \qquad \text{IFIX} = \left(\frac{{}^1\text{FIX}}{{}^0\text{FIX}} - 1\right) \times 100. \qquad (5.4)$$

Similarly using output per firm, firm size indexes are given by

$$\text{prl}_j = \left(\frac{{}^1y_j}{{}^0y_j} - 1\right) \qquad (5.5)$$

$$\mathrm{PRL} = \left(\frac{\sum_{j\varepsilon N} {}^{o}w^{x}_{j}\,{}^{o}y_{j}}{\sum_{j\varepsilon N} {}^{1}w^{x}_{j}\,{}^{1}y_{j}} - 1 \right) \times 100. \tag{5.6}$$

Industry rationalization is usually accompanied by an increase in these indexes. Changes in the actual number of firms may of course either rise or fall depending upon changes in total industry demand, and the rationalization the industry goes through.

The HBCF used in the A and B decreasing cost industries is only an approximation to whatever the true cost structure in the industry is. The issue of choosing these approximations is taken up in section 5.4. For this section it suffices to note that in the benchmark data set there is independent information on the scale of individual output at which cost savings are more or less exhausted. There are referred to as MES output levels, $\bar{y}_j$, an in some simulations output is constrained not to exceed these levels.[36] For practical purposes we therefore define a reasonable level of cost savings that could be achieved relative to base, by having all industry firms produce at MES. This is defined as the *Cost Savings Achievable* index,

$$\mathrm{CSA}_j = \left(\frac{AC_j\left({}^{o}y_j\right) - AC_j\left(\bar{y}_j\right)}{AC_j\left({}^{o}y_j\right)} \right) \times 100. \tag{5.7}$$

This index reports the percentage fall in average costs in moving from base output per firm, to MES output per firm computed at constant factor input prices. This cost saving index does not adjust for actual output produced. It tells how much a given volume of output shared between a variable number of firms producing at MES versus the same output shared between firms producing at base output per firm, y^{o}_{j}, would differ in its total cost of production.

The CSA measures the maximum cost savings possible. Relative to this ideal actual cost savings can be measured. It is necessary first however to adjust for changes in input prices which shift the cost curves of the individual firms. Obviously this is of particular importance in the case of evaluating general equilibrium simulations. To this end define a Laspeyres price index of inputs using base input quantity weights.

$$P({}^{1}Q, {}^{0}Q) = {}^{0}M \cdot {}^{1}Q \;/\; {}^{0}M \cdot {}^{0}Q \tag{5.8}$$

where Q is the vector of input prices in the appropriate period, and M is the vector of input quantities. In situation 1, the comparison equilibrium, an adjusted 'real' or 'constant dollar' cost curve is constructed by defining

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[36] Note that the definition of $\bar{y}_j$ here differs from that used in chapter 5.

$$AC^r(y) = AC(y, {}^1Q) \;/\; P({}^1Q, {}^0Q) \quad \text{for all } y. \tag{5.9}$$

Thus define real *Achieved Cost Savings* as

$$ACS_j = \frac{AC_j^r\left({}^0y_j\right) - AC_j^r\left({}^1y_j\right)}{AC_j^r\left({}^0y_j\right)}. \tag{5.10}$$

Note that since the price index of input prices equals one in the base, any shift in the cost curve caused by changing input prices relative to the base should in principle be corrected for by the input price adjustment. Thus ACS_j measures the change in costs due to *movement along a cost curve*, rather than a *shift in the cost curve*. By comparing ACS with the CSA, an index of the *Degree of Rationalization Achieved* is defined as

$$RAT_j = \frac{ACS_j}{CSA_j} \times 100. \tag{5.11}$$

In a given simulation the RAT number, between 0 and 100 tells the percent of cost savings achieved relative to potential cost savings. An aggregate rationalization index can be constructed by an output weighted index

$$ARAT = \Sigma_{j \in \mathcal{N}}\, RAT_j\, {}^1w_j^x.$$

From the perspective of measuring changes in economic welfare the cost efficiency indexes should be the analogue of the 'rectangles' familiar from basic partial equilibrium theory of rationalization in the face of scale economies.[37] The usual efficiency rectangle is defined as the cost savings achieved due to increased scale on initial output. The aggregate sum of all rectangles in the increasing return industries is thus given in base period prices by

$$RECT = \Sigma_{j \in \mathcal{N}} \left(AC_j^r\left({}^0y_j\right) - AC_j^r\left({}^1y_j\right)\right){}^0X_j. \tag{5.12}$$

These real cost savings on initial output can be expressed as a percentage of either base value-added in all increasing returns industries, base GNE, or base GDP. To the extent that output in the comparison situation is greater than in the base situation the RECT measure will understate the actual cost savings achieved on final output. One could construct a different rectangle measuring the real cost savings achieved on final output, using the weights ${}^1X_j$, final output in equation (5.12). In general though it is recommended to stick with the above definition of the aggregate efficiency rectangle, since it can by usefully used for multilateral comparisons across alternative policy simulations.

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[37] Partial equilibrium 'rectangles' of cost savings and their interpretation are discussed in Harris (1984b), chapter 2.

There are a variety of ways one might construct aggregate indexes of rationalization. One idea is to use the ratio of actual aggregate efficiency rectangles to a hypothetical sum of rectangles assuming that cost reductions would be the maximum achievable. Hence we define RECT as the maximum aggregate sum of efficiency rectangles, given by

$$\mathrm{RECT}^{*} = \Sigma_{j\epsilon\mathcal{N}}\ \mathrm{CAS}_j\ \mathrm{AC}_j\left({}^{o}y_j\right){}^{o}X_j \ /\ 100.$$

By measuring RECT relative to RECT*, this gives an index of the degree of rationalization achieved in delivering the base output mix efficiently.

3.6 Trade Indexes

Conventional indexes on volume, pattern and terms-of-trade are reported. These have the conventional interpretations, and the reader is referred to original references for further discussion.

Intra-industry trade is measured by the Balassa-Grubel-Lloyd (BGL) index of intra-industry trade.[38]

$$\mathrm{Intra}_j = 1 - \frac{\left|V_j^E - V_j^M\right|}{\left|V_j^E + V_j^M\right|} \tag{6.1}$$

where

$$V_j^E = P_{uj}^x\, E_{uj}^u + P_{rj}^x\, E_j^r$$

$$V_j^M = b_j^u\, M_j^u + b_j^r\, M_j^r$$

This index measures the extent to which total two way trade in a given commodity class is balanced. If trade is entirely intra-industry, and there is no *interindustry trade* then $\mathrm{Intra}_j = 1.0$. On the other hand if all trade is interindustry based then the BGL index for all industries will equal 0.0. An aggregate index of intra industry trade, AGTRA, is constructed by weighting the individual indices by their respective shares of total trade volume. Within the GET model because of the existence of non-competing imports, the AGTRA index must always be less than 1.0. Some other definitions:

Trade Volume

$$\mathrm{VOL} = \sum_{j\epsilon\mathcal{E}} V_j^E + V_j^M\, , \tag{6.2}$$

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[38] See Grubel and Lloyd (1975) for a discussion of this index. Helpman and Krugman (1985), pp. 168-169 also discuss the merits of this index in the context of the differentiated products model of two-way trade.

Trade volume commodity shares,

$$w_j^v = \frac{V_j^E + V_j^M}{VOL} \qquad j \in \mathcal{C}. \tag{6.3}$$

The aggregate intra-industry trade index AGTRA is defined as

$$AGRTA = \sum_{j\in\mathcal{C}} w_j^v \, Intra_j. \tag{6.4}$$

Terms-of-Trade indices are computed as Laspeyres price indices (base-weighted ratio of export to import prices). The aggregate terms-of-trade index includes all commodities imported and exported, but similar indices are sometimes reported for subgroups of commodities in an analogous fashion. Let $\bar{E}^k$ and $\bar{M}^k$ denote base export and import vectors by region k = u, r. Then

$$TOT = \frac{\Sigma_{i\in\mathcal{M}} \bar{E}_i^u p_{ui}^x + \bar{E}_i^r p_{ri}^x}{\Sigma_{i\in\mathcal{C}} \bar{M}_i^u q_i^u + \bar{M}_i^r q_i^r}. \tag{6.5}$$

The change in the terms-of-trade is reported as

$$ITOT = \left(\frac{{}^1TOT}{{}^0TOT}\right) \times 100 \tag{6.6}$$

with a positive number indicating the percentage *improvement* in the terms of trade.

Finally there are some indices indicating trade patterns by region. Usually reported as percentage shares of either exports, total trade volume, or percentage shares of a particular regions total market. These figures have the obvious interpretation so no additional comment is called for.

A principal use of GET will be to examine bilateral elimination of barriers between Canada and the U.S. In this context GET is importantly a *three* region model in which the traditional concepts of trade diversion and trade creation emerge, but defy easy definition in a general equilibrium model with differentiated products. In particular the simple idea that trade diversion is welfare reducing, and trade creation is welfare increasing in a customs union between two of the three countries is not valid in a model such as GET.

It is useful however to get an idea of the extent of trade diversion in the context of bilateral tariff elimination, even if not completely theoretically valid. Clearly the reduction in trade barriers between Canada and the U.S. will cause some substitution away from low cost R.O.W. suppliers in favour of higher cost U.S. suppliers. To give an extreme upper bound on this cost it will be assumed artificially that the goods are in fact perfect substitutes contrary to the basic assumptions of the model. The cost of trade diversion in a single market is calculated simply as the difference in the cost before tariffs between the U.S. and R.O.W. product times the reduction in R.O.W. imports. This measure clearly overstates the true cost of trade diversion, not only because it ignores the lack of perfect substitutability between U.S. and R.O.W. goods, but also because it implicitly assumes that the reduction in R.O.W. imports is completely offset by an increase in U.S. imports. In an Armington framework it is quite possible that the domestic good might 'replace' the R.O.W. good. Nevertheless with these qualifications we can define a measure of the cost of trade diversion by commodity as

$$\mathrm{DIV}_i = \max\left[0, -\Delta M_i^r\right]\left(b_i^u - b_i^r\right) \tag{6.7}$$

Note that it possible that R.O.W. imports could decline in a particular commodity, even though the U.S. supply price was below the R.O.W. price. In this case the diversion cost would be negative; this could not be thought of as true trade diversion, but rather only the consequences of general equilibrium adjustments. For this reason diversion is defined as taking place only if DIV_i is positive.[39] An aggregate cost of trade diversion, DIVERT is defined as sum of trade diversion costs divided by base G.N.E., ${}^0I^C$.

$$\mathrm{DIVERT} = \Sigma_{i \in \mathcal{C}} \max\,[\mathrm{DIV}_i, 0] \;/\; {}^0I^C \tag{6.8}$$

To repeat, DIVERT gives an extreme upper bound on the extent of true trade diversion taking place as a consequence of a bilateral elimination of tariffs between Canada and the U.S. It should also be pointed out that when working with non-tariff barriers equivalents of quantitative restrictions the usual measure of trade diversion is entirely suspect. If quotas for example are in place against high cost U.S. suppliers, then any reduction in R.O.W. imports cannot be construed as resulting in a replacement with U.S. imports. A final comment is that any attempt to construct an index of trade diversion relies on being able to identify objectively supply prices in each of the regions from which competing imports come. Equivalently this amounts to having good information on the trade barriers in place against *both* regions exports, and not just on those barriers in Canada and the U.S. which are reduced as a result of the bilateral elimination of barriers.

An index of trade creation is not as easily constructed, largely because the definition of trade creation in the customs union literature is a good deal less clear than that of trade diversion.[40] Rather than trying to construct a welfare relevant measure of trade creation, it is probably better to simply report descriptive statistics on changes in trade volume between different regions. In the case of a reduction in barriers between Canada and the U.S. one would be interested in the extent to which trade volume between the regions increases.

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[39] It is also worth pointing out that the DIV measure assumes that low cost R.O.W. imports are replaced with high cost U.S. imports, and not high cost domestic goods. It is possible that the U.S. good is not competitive with the Canada and R.O.W. good, and the general equilibrium effect of the Canada-U.S. F.T.A. is to reduce R.O.W. imports. It would be possible to amend the definition in (6.7) to account for this reasonably straightforward.

[40] See Corden (1984) for a review of the rather confusing debate on trade creation and trade diversion.

3.7 Other Indexes

Depending upon the policy simulation it will be convenient to report other indexes. For example a Domestic Producer Price Index is sometimes reported as

$$PR = \left(\sum_{j \in \mathcal{M}} w_j^x \, {}^1P_j^c \right) \Big/ \sum_{j \in \mathcal{M}} w_j^x \, {}^0P_j^c \qquad (7.1)$$

Indexes of value added, real and nominal, and measures of effective protection are also defined in the obvious way.

In the simulation output some attempt is made to report the extent to which resources shift intersectorally. Any such measure might be used to give a rough idea of the extent to which adjustment in the economy might be caused by the shock imposed on the model. There are various ways this might be done, but one that is probably most understandable and most relevant from the policy perspective is to measure how labour shifts intersectorally. This turns out to be particularly simple when the labour supply is inelastic and full employment occurs both before and after the shock.[41] The index measures quite simply the percentage of the labour force which must move between sectors as a result of the shock. Clearly the lack of a skill-regional dimension to the labour force makes this less than adequate measure of adjustment; nevertheless it is quite useful in guaging how policies produce intersectoral reallocations of resources. The index is denoted by REALLOC, and defined between two situations as

$$\text{REALLOC} = \Sigma_{i \in \mathcal{M}} \max \left[0, \, {}^1L_i - {}^0L_i \right] \Big/ \bar{L} \qquad (7.2)$$

In the CGE literature there has been little in the way of attempts to measure differences between resource allocations, and thus no established way of reporting results has yet to emerge. There is clearly room for additional research. In interpreting such indexes it is important to remember that one is not talking about resource *flows* as a consequence of a policy shock; to do so would require a dynamic model. Rather one is only comparing two resource allocations after all factor flows between industries have ceased.[42]

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[41] In the short run model GET-S discussed in chapter 4 unemployment is assumed to exist in all industries. It should be noted that a measure of intersectoral reallocation of resources is not valid in that context as the underlying assumption is that changes in economic activity within the short run are principally changes in the *utilization* of resources within each industry, rather than shifts in resources between industries.

[42] One idea worth exploring in this framework would be to construct Gini indexes of the distribution of employment or output across sectors. Changes in the Gini coefficient would give some handle on the extent to which the economy becomes more or less specialized with respect to the industrial mix as a result of a particular shock.

Chapter 4

A Short-run Version of the GET Model

4.1 Introduction

This chapter outlines the short-run version of the GET model, hereafter referred to as GET-S. The basic purpose of this model is to focus on the impact of trade policy, and other model shocks, given assumptions about the nature of equilibrium in the economy over the relevant time frame, assumed to be in the range of six to eighteen months. The model can be used to estimate the effect of tariff reductions on output, prices and employment given assumptions about elasticities and determinants of expenditure. It is not surprising that as soon as one moves from models of the 'long run' to models of the short run there is considerably more controversy as to the exact nature of the factors determining prices and quantities; indeed one is put squarely in the centre of the debate on macro-modelling to a considerable degree. It is to be emphasized at the outset that the current version of the GET-S model does not make any innovations in the treatment of macroeconomic closure. It uses a quite conventional macroeconomic closure used elsewhere in the CGE literature; rather the contribution of the model to policy analysis is to provide a means by which disaggregated impact effects are generated using a general equilibrium methodology which connects all markets. Much of the interindustry structure of the GET-S is similar to GET. This has the added advantage that GET-S can be used as a means of isolating 'first-round' effects of the longer run model. This is of obvious use in understanding the results generated by the long run model.

It must be realized that the short-run version of GET is not intended as a model which serves to investigate potential rationalization effects, or the welfare impact of policy changes. Rationalization is not possible as the number of firms is held fixed in GET-S simulations. The model is intended as more of a descriptive device for tracking short term price and output effects taking the existing structure of industry as given. Likewise GET-S is not useful as a tool for welfare analysis. Because the balance of payments is in disequilibrium in this model, and government budget balance is not assured there is little normative content in conventional consumer surplus measures. One must be wary for example of ascribing a welfare improvement in the case of a fall in prices, or an increase in employment if this is accompanied by an increase in the balance of payments deficit. While it is possible to do welfare analysis in fix-price disequilibrium models it is a practice which remains sufficiently controversial that emphasis on this aspect of the modelling project is not justified.[42]

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[42] Roussalang and Young (1984) discuss the theoretical interpretation of welfare cost of the tariff in the presence of unemployment. An important paper which uses welfare costs together with an ad hoc adjustment cost number in a model similar to GET-S is Baldwin et. al. (1980). Harris et. al. (1981) provides a criticism of these methods. What is clearly called for is a more explicit dynamic model. It may be however that the less satisfactory welfare measures proposed in the papers cited above are practically the best that can be hoped for. Further research is warranted on this topic.

The basic macro model underlying the impact version of GET can be found in most textbooks on international macroeconomics. The model is closely related to the Keynesian model of the open economy which assumes rigid factor prices, unemployment and a fixed. nominal exchange rate. Indeed the model of Dornbusch (1980), chapters 3 and 4 is for all intents and purposes the basic macro model underlying the impact version of GET.[43] The model assumes unemployment in all industries, with fixed nominal wages and a fixed exchange rate. All markets other than the labour market however are assumed to clear, and prices are set in accordance with a short-run markup theory of pricing. The asset-financial side of the economy is ignored through the assumption that the exchange rate is fixed, and the interest rate is fixed in world markets. Any financial flows which result from the assumption that these asset prices are fixed in the economy and their impact on expenditure are ignored in the time frame assumed relevant for the model. The principal macro feature of the model shows up through assumptions made on the determinants of aggregate expenditure. Macroeconomic equilibrium is a reflection of the income equal expenditure condition; given the existence of disequilibrium in the labour market the trade account is necessarily in either surplus or deficit. Much of the interest in the model centres on how the change in tariff structure, or other forms of protection, both foreign and domestic affect the trade balance.

This type of analytical structure is quite common in CGE modelling; both the World Bank models[44] and the ORANI model of Dixon et.al. (1981) fall in this tradition.[45] While not wishing to defend this particular macro closure rule as being eminently the most sensible, its main attraction stems from the ease of implementation given the full-employment version of the model already exists, and fairly straightforward interpretation of the results produced by the model.[46]

4.2 Expenditure Determination

As noted above the key aggregate behavioural equations of the model, other than fixed nominal wages, is the assumptions underlying the determination of aggregate expenditure. Income is denoted by I and aggregate expenditure by E. Demand functions depend on E; thus the demand equations of chapter 3, 3.3 -3.5 are similar in structure except that E replaces I^C.

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[43] The main distinction worth pointing out between the model in Dornbusch and the one used here is that GET assumes rigid nominal wages, while at times Dornbusch assumes rigid real wages.

[44] See Dervis et. al.(1982) for a description of the World Bank CGE models.

[45] The models of Deardorff and Stern (1979) and Baldwin et. al.(1980) are also closely related to GET-S in their basic theoretical structure. The VARUNA model of Ginsburgh and Waelbrock (1981) also seems to have a related macro structure.

[46] Calibration of the short-run model raises some issues unique to this type of modelling. These are taken up in an appendix to this chapter. The reader may wish to leave this section until having read chapter 5.

Aggregate expenditure is determined by an equations of the form

$$E = W L^d + \delta_s DSS + \delta_e E_o \qquad (2.1)$$

The first term on the right hand side of (4.1) is labour income; the nominal wage is exogenous, but L^d, total labour employed is endogenous. The marginal propensity to spend out wage income is one. DSS is the sum of residual payments to non-labour factors of production, including any rents or quasi-rents present in the system. E_o includes transfers either from foreigners, or the government sector and the value of sales of exogenous final supply. In particular it is assumed that changes in net government revenues due to changes in tariffs accrue back to consumers through changes in net government transfers. All three components of expenditure are endogenous within the time frame of the model.

A given level of expenditure E, given prices and wages gives rise to a set of demands by industry, which, given the assumption of unemployed resources in all industries, implies a certain level of aggregate labour demand, $L^d(E)$, and aggregate surplus, DSS(E), plus transfers, $E_0(E)$. Substituting these back into equation (2.1), setting $\delta_s=1$. $\delta_e=1$ and $c_o=0$, gives an equation the left hand side of which can be interpreted as aggregate income, given an expenditure level E. Equating income to expenditure determines the equilibrium level of expenditure in the economy. The δ_s and δ_e coefficients in (2.1) reflects the marginal propensity to spend out of non-wage income. These parameters could be set equal to 0, or possibly some number less than one; it should be noted that since consumption and investment expenditures are aggregate the propensity of firms to spend out of internal funds must be accounted for. The d_o term must be adjusted so that in the benchmark total spending equals total income I^o. An additional possible complication is the change in net government revenues which are not returned to households and firms; it is possible to neutralize these effects on the government budget constraint by changing other taxes. Dornbusch discusses this for example in the case of an export subsidy (1980, pp. 66-67) In the present version of GET-S revenue changes due to tariffs are neutralized through changes in a tax on labour income.

4.3 Substitution in Production and Consumption

The pattern of substitution in the production structure is quite different in the GET-S model, than in the long run model. Intermediate commodity inputs are assumed to be used in fixed proportions over the relevant time frame; thus no substitution between intermediate inputs is possible. Hence for each commodity i there is a Leontief aggregator function giving total output as a function of the vector of material inputs M_j, and variable capital and labour used in that sector:

$$X_j = \min \left[\left\{ \frac{M_{ij}}{a_{ij}} \right\}, \frac{L_j^v}{a_{nj}}, \frac{K_j^v}{a_{kj}} \right] \tag{3.1}$$

The a_{ij} coefficients are the *aggregate* input-output coefficients for each material input. Each material input M_{ij} is an Armington CES aggregate of the respective Canada, U.S. and R.O.W. inputs. Thus for example letting the appropriate superscript denote the relevant region we have

$$M_{ij} = \beta_{ij} \left[\lambda_{ij}^{c} {M_{ij}^{c}}^{\varepsilon} + \lambda_{ij}^{u} {M_{ij}^{u}}^{\varepsilon} + \lambda_{ij}^{r} {M_{ij}^{r}}^{\varepsilon} \right]^{-1/\varepsilon} \tag{3.2}$$

The substitution parameter ε is commodity specific. It is assumed that the substitution parameter, or Armington substitution elasticity $\sigma = 1-1/\varepsilon$ is the same in both production and consumption. This assumption while common is not really justifiable. The rationale is that commodity aggregates are the same across industries, and is the same aggregate which is an input to consumption.

On the the primary factor side, it is assumed that capital services are in excess supply, but the capital stock is fixed in all firms, in all industries. Furthermore the period is sufficiently short that investment or depreciation has no effect on the capital stock in place. Hence the capital stock is fixed, but effective services of capital adjust to meet the output requirements of industry. Capital stocks which arise from the fixed cost aspect of the technology are also given, but put no constraint on the level of output in each industry. Labour services are assumed to match one-to-one with employment, and thus changes in the level of output affect the amount of labour services used by the identity $L_i^v = a_{ni} X_i$. Fixed labour in each industry is assumed to be fully employed. It is assumed that capital services, labour and material are all used in fixed proportions. Thus technology is assumed to be of the putty-clay sort, with short run fixed proportions, but long run substitutability.

4.4 Pricing Behaviour

The only relevant aspect of industrial organization used within the model is the assumption of short-run markup pricing, with the markup on short-run marginal cost. Short-run marginal cost includes material and labour costs, but excludes capital costs. The number of firms is assumed to remain fixed, and thus industry rationalization is not feasible within the time frame envisaged.

Within this general framework we imagine two possible alternative pricing rules for the A industry group. One is a fixed markup rule analogous to MCH pricing but even more limited in that the actual markup is fixed; in particular it does not change with a reduction in the domestic tariff. The second pricing rule is the Eastman-Stykolt hypothesis of pricing to tariff plus world price. In this case domestic markups are endogenous, and change with changes in either tariffs, exchange rates, or foreign prices--anything changing the competitiveness of domestic versus foreign prices--results in a change in markup to preserve competitiveness. Formally the pricing equations are analogous to those in chapter 2 except that long-run marginal cost, v_i, is replaced with short run marginal cost smc_i. Let $sv_{ij}(P)$ be the dual unit cost function to (3.2). Then short run marginal cost in industry j is given by

$$smc_j = a_{nj}W + \sum_{i\epsilon C} sv_{ij}(P) \tag{4.1}$$

The markups under each hypothesis are calibrated to this marginal cost. In the B, 'contestable' industries markups are assumed to be unaffected by tariff changes. In the short run these markups are taken as exogenous, equal to the observed markup in the benchmark.

4.5 Evaluating Tariff Cuts

The impact of a tariff cut in this model is quite different than in GET. The essential mechanics of the macro effects are discussed in Dornbusch (1980), chpt. 4, and illustrations of these type of results are contained in Dixon et. al. (1981) and Dervis et.al. (1982).

The difference between a competitive G.E. model and non-competitive model such as GET have little role to play in this type of analysis. Although there are static scale economies present, given the presence of short-run fixed costs scale economies exist in the short run in a competitive model with under-utilized factors. Definitions of factor utilization in both models should include all relevant factors; in the GET-S model one must account for capital and labour which is fixed in both the long and short-run but changes only with entry and exit. Productivity will obviously change with movements in output in the short run.

More traditionally models such as these focus on the impact of the trade balance on aggregate absorption. A bilateral cut in tariffs has both an expenditure switching effect, and an expenditure increasing effect. The expenditure switching effect comes from the lower foreign prices with the domestic tariff cuts, holding export prices constant. The reduced demand for domestic goods results from an increased marginal propensity to import, as a result of the lower price of foreign goods. This import substitution effect reduces aggregate demand, lowers income and employment, and leads to a deterioration in the trade balance. The reduction in U.S. trade barriers lowers prices paid by U.S. consumers of Canadian goods and hence increases the demand for Canadian exports; this gives rise to an increase in the aggregate demand for Canadian goods which raises income and employment via the traditional trade multiplier. Reduced Canadian import barriers also increase demand for Canadian production through either a direct effect on export prices via the Eastman-Stykolt pricing effect, or through reduced costs of intermediate imported inputs which lowers domestic costs and thus reduces both export prices and domestic prices of non-tradeables and import competing goods. All of these effects are demand increasing.

4.6 Productivity and Employment

One of the principal purposes of this model is to estimate the impact effect on labour demand of reduced trade barriers. Given the absence of substitution in production changes in output translate into changes in labour demand using the equation

$$\Delta L_i = a_{ni} \Delta X_i \qquad (6.1)$$

Much of the interest in tariff reduction has focused on possible improvements in productivity from the rationalization process accompanying liberalization. It is possible that extraneous estimates on productivity change can be used to suggest that a new set of labour requirements coefficients will be in place over the short term. Thus assume that

$$a_n^* = a_n (1-\tau) \qquad (6.2)$$

where τ is the rate of productivity improvement and a_n^* is the post liberalization labour requirements coefficient. Use of such exogenous changes in productivity can be quite helpful, particularly if anticipation effects are important in the liberalization process. For consistency prices must be computed using the new productivity coefficients. The productivity increases lead to lower prices for most commodities. At the same time the improved labour productivity reduces the increase in demand for labour in those industries which expand, and increases the reduction in labour demand in those industries which contract. Therefore if a particular cut in protection without a change in productivity shows itself to be on balance employment creating, by raising labour productivity the increase in employment will be lower than it otherwise would be.

4.7 Alternative Macro Closure Rules

The value of these impact exercises are heavily conditioned by the particular macroeconomic equilibrium assumption used, or 'macro closure rule' as discussed in the introduction. The ones adopted thus far are used basically because of their simplicity and also because they have been used considerably in the past. There are a number of alternatives however to either the basic assumptions made on exchange rates, wage rates or aggregate real expenditures.

1. Rather than rigid nominal wages, it sometimes assumed that real wages are rigid. Nominal wages are deflated by an index of consumer prices to get a real wage index. This type of assumption sometimes leads to the 'peculiar' result that nominal .wages are cut in the face of a trade liberalization because prices fall with tariff reductions.

2. A fixed exchange rate assumption is replaced with some theory of exchange rate determination. Deardorff and Stern (1979), for example, use trade account balance to determine an 'equilibrium' exchange rate. Some models have resorted to a monetary theory of exchange rates, through explicit modelling of money supply and demand. A number of other alternatives exist, but our knowledge of exchange rate determination over short horizons is sufficiently weak as to render almost any assumption suspect. For these reasons, given that the purpose is to focus on the impact effects of tariff

reduction, changes a fixed exchange rate assumption seems appropriate if not factually accurate. The assumption obviously is more legitimate to the extent that exchange rates are managed as opposed to free floating.

3. Aggregate expenditure and employment. CGE models have used a variety of assumptions regarding the determination of aggregate expenditure, from explicit modelling of consumption and investment to a variety of 'compensating mechanisms'. Two common compensating mechanisms are a) adjusting aggregate government expenditure to keep the initial employment level constant, or b) adjusting the level of government expenditure to keep either nominal or real aggregate absorption constant.[47] When compensating mechanisms are used it is usually for the purpose of isolating the microeconomic relative price effects from macroeconomic effects of the policy. This may be useful, but it depends upon the purpose of the analysis. Clearly if the effect is to estimate employment effects of changes in protection either of these assumptions is suspect. On the other hand when the purpose is to estimate the necessary adjustment in policy tools in order to preserve certain targets of economic policy, either of these assumptions may be quite sensible.

The GET-S model can be incorporate any of these assumptions in a straightforward way. The basic interindustry-pricing framework, together with basic assumptions on technology and substitution remain unchanged given alternative assumptions about macro closure. More problematic though is the assumption that all industries are in a state of excess capacity both with respect to capital and labour.

If supply constraints bind in any industry either because of labour shortages or capacity limitations which are industry specific it is analytically and practically quite difficult to change the GET-S model to accommodate these limitations as the model is now coded. From the trade policy viewpoint accounting for short run supply constraints could be very important. A bilateral tariff cut may well induce existing industries to operate at capacity. In these industries it would be realistic to expect price increases rather than output increases. To the extent these industries are export oriented this would constitute an improvement in the terms of trade, rather than in the volume of trade. Moreover reductions in labour demand in import competing industries which results in excess capacity and unemployment will not be offset by increases in employment in export oriented industries to the same extent simple trade multiplier analysis would suggest.

Conceptually there is no difficulty in imposing on the model the existence of supply constraints. In those industries prices now adjust to reflect supply equal demand, rather than a markup on cost, with output demand determined. The general equilibrium determination of prices and quantities however is far from simple, and a number of difficult algorithmic issues arise. Because it may be desirable in the future to work with supply constrained versions of the GET model it will be useful to outline the amendments to model structure and algorithmic adjustments required.

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[47] The former is used by Brown and Stern (1986) and the latter by Dixon et al. (1978).

4.8 A Supply Constrained Version of GET-S

Probably the simplest approach to modelling supply constraints is to explicitly introduce industry specific factors (capital, labour, other) into each industries production function giving rise to a Ricardo-Viner trade model, although implemented over a short run with some appropriate macro closure rule. The Cox (1987) thesis essentially accomplishes this for the long run version of GET. In this model each industry has an upward sloping supply curve and prices adjust to equate supply and demand. The major difficulty with this method is two-fold. First, it does not give a model which is easily interpretable in terms of excess capacity, unemployment or full capacity; rather different industries are simply on different parts of the supply curve; the modeller must interpret the supply curve in terms of regions of over and underemployment of resources specific to the industry. Second, this formalization does not allow for price rigidities. The alternative is to recognize ex ante the existence of exact supply constraints motivated by capacity or labour constraints. With these in mind it is possible to design solution algorithms which solve for price and quantity.

Consider first the general problem. Let the demand functions be denoted by $F_i(P,E)$, for $i= 1,\dots,n$. P is the price vector and E is aggregate expenditure. Let S_i denote the supply constraint for industry i. Equilibrium requires that

$$F_i(P,E) \le S_i \ , \text{ for all } i = 1,\dots,n. \qquad (8.1)$$

However prices are bounded below by B_i. For the moment we assume these bounds are exogenous. Thus an equilibrium is a set of prices P^* such that

$$(1) \quad F_i(P^*,E) = S_i \quad \text{if } P_i^* > B_i \ ,$$

and

$$(2) \quad F_i(P^*,E) < S_i \quad \text{if } P_i^* = B_i. \qquad (8.2)$$

Numerically such a system can be solved by solving for a solution of the system of equations

$$[F_i(P,E)-S_i]\circ[P_i-B_i] = 0 \quad i=1,\dots,n. \qquad (8.3)$$

Traditional Newton methods for solving simultaneous non-linear equations can be applied to (8.3).

In the context of the economic structure of GET-S, to operationalize simultaneously supply constraints and rigid factor prices it must be recognized that the lower bounds on prices are necessarily endogenous. Let $smc_i(P,W)$ denote the short run marginal cost functions and δ_i the relevant markup used in setting prices. For industries in excess supply the relevant constraint on prices is that

$$P_i = \delta_i \; smc_i(P,W) \tag{8.4}$$

Otherwise prices are determined by demand equal supply. Likewise expenditure must adjust such that the income expenditure equilibrium condition hold. Given a level of expenditure E and vector of prices P the demand determined vector of gross outputs can be computed as outlined in chapter 2.4. Denote these as X(P,E). Likewise given P and E the income consistent with these demand can be denoted by I(P,E) as implicit in equation (2.1). An equilibrium then is a P^* and E^* such that

$$[smc_i(P^*,W)-\delta_i P_i^*]\circ[X_i(P^*,E)-S_i] = 0$$

$$I(P^*,E^*) = E^* \tag{8.5}$$

One should check the solution of (8.5) that the relevant inequalities are satisfied, but an economically sensible model should satisfy these constraints automatically. The solution of (8.5) could be calculated by a number of numerical methods available in current software. However for large scale models solution time might be substantial.

In summary the addition of supply constraints to short term models would add significantly in terms of realism, and such methods are clearly feasible in practical terms given current computing power. CGE analysis as a tool for impact analysis would be improved significantly if such methods were used, together with the relevant data on short run supply constraints.

4.9 Conclusion

In this chapter we have summarized how the GET model can be amended for the purposes of doing impact analysis on prices, outputs, and employment. The important issue of macro closure was discussed. One particular macro closure rule was introduced and the basic model structure discussed. Additional closure rules used in the literature were reviewed, as well as the problem of introducing supply constraints in an otherwise demand determined model. While not yet incorporated within GET-S it was suggested how these supply constraints could be introduced.

Appendix: Calibration of GET-S

This appendix is most usefully read after the reader has gone through the material in chapter 4. This appendix describes the calibration of the GET-S model as implemented in the program TESTK for use within the simulation program PILOTK. An important difference between the GET and GET-S benchmarking/calibration procedures is that in GET-S there is no difference between the benchmark data set and the base equilibrium data set. As changes in market structure are ignored within GET-S and short run balance of payments disequilibrium can be assumed to persist (non zero BOP) the basic benchmark of TEST is used as the relevant equilibrium which is shocked for purposes of short run impact analysis. Thus the equilibrium calculated within PILOTK holds constant

i) the number of firms in A and B sectors

ii) the balance of payments deficit, BOP

iii) exogenous final supplies, XFS, and the income from these sales, VXS.

The calibration program is similar to the calibration program associated with GET, but has some obvious differences as a result of differences in model structure elaborated upon in this chapter. The whole issue of zero economic profits, for example, is irrelevant in the GET-S model and hence in the calibration exercise. Beyond this the principal differences are as follows.

1. It is necessary to compute short run variable marginal costs in each industry. All capital is assumed fixed within the relevant time frame of GET-S. However it is still necessary to estimate scale economies and fixed labour requirements by industry, in order to subtract fixed labour costs, from total labour costs to get a measure of variable labour costs which are assumed to be avoidable costs within the time frame of the model. Variable labour costs are included in the definition of short run marginal cost.

2. Markups are calculated on short run marginal cost by taking the ratio of observed price to short run marginal cost, adjusting for producer subsidies. The same pricing rules for the A industries are used as in GET.

3. Calibration of export demand and domestic utility function parameters is left the same as in the TEST program.

4. Technology in all industries has a different functional structure than in GET as described in this chapter. It is necessary to calibrate the aggregate input-output matrix A which is not region dependent, as well as the coefficients of the Armington aggregators for each material aggregator in each industry. Variable labour input requirements coefficients, a_{nj} are also required for each industry.

5. In the calibration of income, the surplus variable DSS is computed as a residual, by subtracting all income sources, including labour income,

BOP, GOV, and VXS from expenditure I^c in the benchmark. Note that AGPROF is not calculated separately; quasi-rents on capital are included implicitly in DSS.

6. Basic elasticity values which are inputs to TESTK should be set at appropriate values for short-run analysis. Typically these would be one-half to one-quarter of the long run values.

7. If labour is assumed to be intersectorally immobile it is possible to introduce arbitrary inter-industry wage differentials. If this is done labour income in both TESTK and PILOTK must be calculated appropriately.

8. Government expenditures on capital subsidies must be carefully used in both programs. If used they must be converted to values which do not change in the course of the solution of PILOTK. That is the model must not inadvertently show changes in capital subsidy payments, when all capital is assumed fixed. Subsidies to labour must be careful to pertain only to labour employed, and not the labour force in each sector.

Chapter 5

Calibration and the Base Equilibrium Calculation

5.1 Introduction

In this chapter the methodology and specifics of calibrating and benchmarking the long-run GET model is described. In section 5.2 a general discussion of benchmarking is provided, and some of the issues unique to working with imperfect competition models are taken up. Section 5.3 takes up data requirements for calibration. Section 5.4 deals with the issue of approximating cost functions in increasing returns industries. Sections 5.5 through 5.8 cover the details of calibrating parameters in all relevant cost and demand functions of the model. Section 5.9 returns to the details of calibrating conjectural variations in the pricing equations of the model. Section 5.10 discusses how endowments of capital income are constructed and the last section contains a general discussion of the differences between historical benchmark data sets and equilibrium data sets which are suitable status quo equilibrium for the purposes of comparison in conducting policy counterfactual experiments.

Calibration of GET-S, the short-run model is not discussed in this chapter. Readers familiar with the calibration of the long-run model should have little difficulty understanding the mechanics of calibrating GET-S.[48]

5.2 Benchmarking and Calibration with Imperfect Competition

The process of benchmarking CGE models is now reasonably well established. Discussions of the procedure are provided in Whalley (1985) and Mansur and Whalley (1983). The reader is assumed to be familiar with the basic idea of benchmarking in constant returns perfect competition models. There are some problems which arise in this procedure which are both important and controversial. You will recall that the basic idea in calibration is that the model must produce as a *benchmark equilibrium* the data set collected for the actual economy (or economies) of a given historical period. The problem is that the idiosyncrasies of a particular year's data may be such that the theoretical assumptions underlying the equilibrium concept of the CGE model may be mutually inconsistent. Independent of this consistency problem, the investigator may not be satisfied with the particular data set being used as the benchmark for purposes of counterfactual analysis. This could arise for example if the data contained price and output observations which were thought to *atypical* for the time period under study, or alternatively some changes had occured in the economy which made particular features of the data set irrelevant for current policy analysis. For both of these reasons it may be desirable to produce a hypothetical data set which must satisfy the theoretical consistency requirements imposed by the particular model in use, and which the investigator feels is a reasonable data set from which counterfactual policy analysis can be carried out. In this manual this latter data set will be referred to as the *base equilibrium*, and the actual historical data set will be referred to as the *benchmarking data set*. We shall address the problem of how to go from the benchmark data set to the base equilibrium, or more concisely as to how to go from a benchmark to a base.

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[48] See the remarks in the appendix to chapter 4.

The first problem to arise occurs in the treatment of capital income, and thus parameterization of factor intensities and production structure in the model. The usual procedure is to derive factor input shares off an input-output table *assuming zero economic profits in all industries is a correct assumption for the benchmark period*. Making the zero economic profit assumption is of great value in simplifying the calibration procedure, but unfortunately is likely to lead to large errors in imputing the true factor intensities of different sectors. The obvious problem is that an industry might be suffering from an abnormally low price in a particular year, and this in turn would result in short run economic losses, or a very low imputed income to capital using a residual calculation such as using operating surplus off an I.O. table. There are various ways one might imagine correcting for this problem; one could collect data for a number of years and try to use some averaging procedure as a device of producing a *typical long run*. An alternative is to use other data sources on capital stocks and capital service rentals, and thus identify the discrepancy between the observed short run and the true long run factor intensity. This is essentially what is done in the GET calibration procedure. The cost of doing so however is that the benchmark can obviously no longer serve as the base, except possibly only in very limited short run interpretation.

A second set of issues arise with respect to imposing the theoretical assumptions underlying the model of imperfect competition used within the model. The two basic equilibrium conditions of the GET partial equilibrium industry model pertain to industry output per firm, y, and the number of firms in the industry , ν. These conditions are:

(1) Free entry/exit assures zero pure profits so

$$P = AC(y) \tag{2.1}$$

and

(2) the relevant theory of pricing requires

$$\frac{(P-MC(y))}{P} = \frac{1}{|\varepsilon|} \,. \tag{2.2}$$

where ε is the price elasticity of perceived demand, and $MC(\circ)$ is the marginal cost function. The elasticity ε can be thought of as reflecting underlying parameters of the model and oligopolistic behaviour. On the other hand the difference between average and marginal cost reflects the degree of scale economies underlying the cost function. *Even if* one takes the zero economic profit assumption as reasonable, it is not possible to simultaneously adopt independent hypotheses on i) scale economies existing at the observed equilibrium, ii) the number of firms; iii) the structural parameters underlying the pricing parameter ε. So , for example if one takes the number of firms ν as given, and output per firm y, together with a cost elasticity determining the degree of unexploited scale economies, θ=MC/AC, then the zero profits hypothesis implies that ε is determined residually.

For those calibrating imperfect competition models, the procedure adopted to get out of this particular straightjacket is to introduce a parameter cv, referred to as the *conjectural variations* parameter. In this case, the pricing rule is amended to the form

$$P = cv\ \Delta\ MC \qquad \Delta = (1-1/|\varepsilon|). \tag{2.3}$$

The advantage of this formulation is that underlying structural parameters affecting ε remain as part of basic model structure, but the parameter cv is chosen such as to ensure the zero profit condition holds. This procedure while helpful poses additional difficulties if zero economic profits is not appropriate. The procedure adopted in the calibration of GET is as follows.

1. Information on the number of firms, output per firm, scale economies, average cost, pricing parameters (ε), and price (or total revenues) is collected.

2. Marginal cost is determined using the information on scale economies, or cost function elasticities, and observed average cost.

3. The cv parameter is determined by approximating long run equilibrium price, P^*, by average cost, AC, and solving the pricing rule for the cv parameter given P^*, MC, and ε.

4. Price, or equivalently, total revenues and total costs remain independent of one another in the benchmark. Total cost for example reflects assumptions regarding the opportunity cost of the capital stock services being used in the benchmark. Thus in the benchmark firms earn positive or negative economic profits, and hence (2.2) is *not* satisfied, and (2.3) does not hold exactly.

In order to get a *base equilibrium* data set it is necessary that two conditions be imposed on the data, not present in the benchmark data set.

1. Economic profits must be zero in all industries
2. Prices must be set in accordance with the underlying pricing theory of the model, equation (2.3).

This can be accomplished given that all parameter values have been calibrated prior to imposing zero profits and the correct pricing rule. Imposing these two conditions is how the *base equilibrium* is computed. It is useful therefore to think of the transition between the bench and the base as imposing these two additional conditions on the model structure, assuming all other model equilibrium conditions hold in the benchmark. At the partial equilibrium level it is possible to see what is likely to happen in calibrating the cv's by the two possible methods.

In each industry i a theoretically determined gross markup m_i^* is multiplied by a conjectural variation coefficient cv_i, so that the actual markup $\bar{m}_i$, is given by $cv_i \times m_i^*$. Elasticities and Eastman-Stykolt effects determines m_i^*, but cv_i must also be calibrated by choosing a relevant $\bar{m}_i$. How one chooses $\bar{m}_i$ will determine some properties of the model consistent benchmark, and how it differs from the observed benchmark.

Two possibilities suggest themselves in the choice of $\bar{m}_i$. One is to choose the markup as observed price, $\bar{p}_i$, over observed cost. Figure 5.1 illustrates this procedure for two cases in a hypothetical industry. $\bar{y}$ is output per firm in the observed benchmark and v is observed unit cost. In case I the average cost at $\bar{y}$ exceeds $\bar{p}$ so the industry is experiencing economic losses. If price is set by using the observed markup so $\bar{m} = \bar{p}/v$, in case I the transition to a consistent benchmark would involve firms exiting, so to an approximation output *per* firm increases to $\hat{y}_1$. In case II, the industry is experiencing positive profits in the observed, and the move to the consistent benchmark would mean a reduction in output per firm to $\hat{y}_2$.

An alternative procedure and one used in the existing version of GET is to choose the markup $\bar{m}_i$ so that in the transition to the benchmark *prices* would adjust on impact to ensure zero profits, and hence the number of firms would remain relatively stable. This is illustrated in Figure 5.2

Using the markup $\bar{m} = \overline{AC}/v$, will have the effect that on using this markup to calibrate the cv price will fall to $\overline{AC}$. The change in prices will cause a series of second round and subsequent effects, but the major adjustment in going from the benchmark to the base equilibrium will be a change in domestic prices, and not a change in industrial structure. As industrial structure is thought of as more permanent than prices this may be more reasonable. The second procedure for calibrating markups produces a base equilibrium which is consistent with the observed benchmark industrial structure, but not necessarily observed benchmark prices.

A slightly different, but related problem occurs in the contestable export industries. In those industries the number of firms does not change, but the average cost pricing rule produces varying markups. In the benchmark since price does not equal average cost, there will be transition effects in going from the benchmark to the base. Generally speaking price will fall, and output expand in those industries which exhibit economic profits in the benchmark, and conversely price will rise, and output contract in those industries with economic losses in the benchmark. Since only condition (2.1) need hold in the contestable industries the additional degree of freedom would allow the use of a benchmark as a consistent base provided the zero economic profits assumption is acceptable. Imposing zero profits on contestable industries in the benchmark is not used in the current version of GET, but it has the obvious advantage of reducing discrepancies between the benchmark and base.

Figure 5.1

Calibrating Markups to Observed Price Over Unit Cost

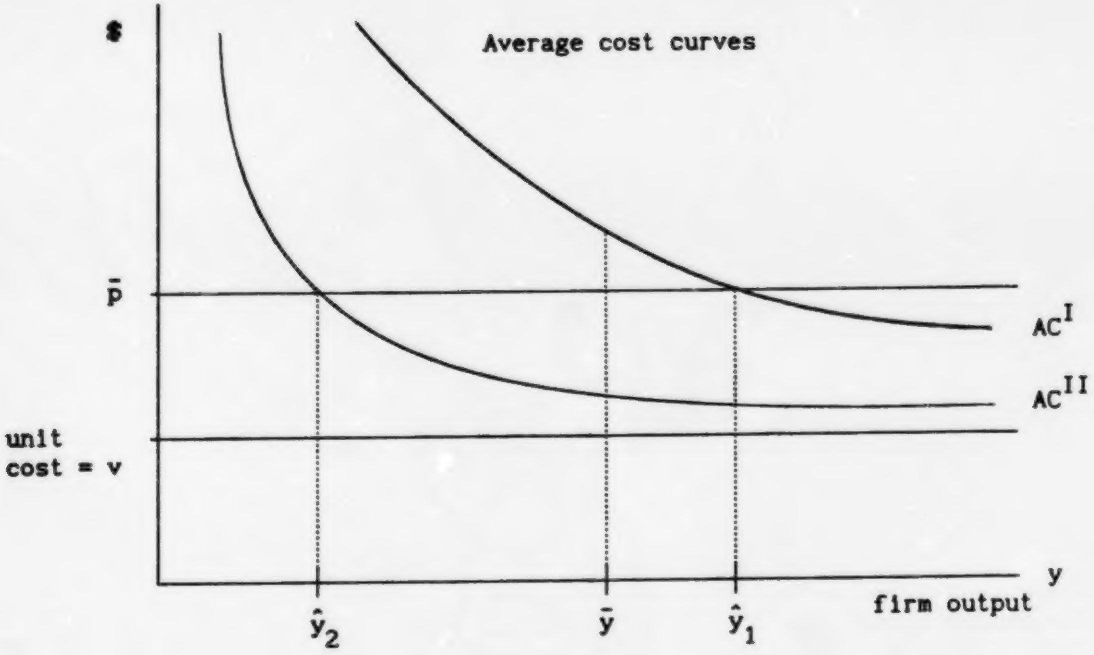

Figure 5.2

Calibrating Markups to Observed Cost Over Unit Cost

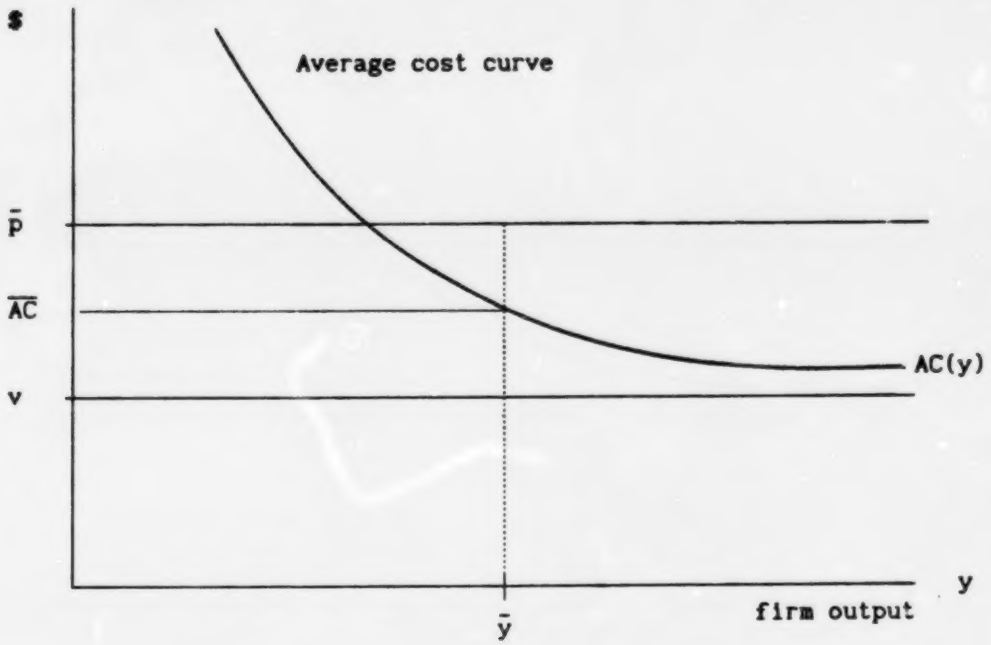

Table 5.1

Data Requirements for Calibration Program

Product and Income Flows (evaluated at producer prices)

Domestic Final Demands	D_i^c, D_i^u, D_i^r
Exports by Region	E_i^u, E_i^r
Intermediate use of Commodity i, Region k, by Industry j	YY_{ij}^c, YY_{ij}^u, YY_{ij}^r

Factor Income and Quantities (1981 producer prices)

Wage Bill by industry	WB_i
Capital Stock by industry	$KSTOCK_i$
Capital service rentals by industry	r_j

Industrial Structure and Cost Data for Manufacturing Industries

Number of firms	ν_j
M.E.S. output per firm	y_{mj}
C.D.R. ratio	cdr_j
Cost saving achievable	CSA_j
Capital/labour ratios	k_j
Cost elasticity	ε_j^{COST}

U.S. and R.O.W. Trade Patterns

Share of total U.S. expenditures on commodity i accounted for by imports from Canada	$IPRC_i$
Share of total U.S. expenditures on commodity i accounted for by imports from R.O.W.	$IPRR_i$
Exports of U.S. commodity i to R.O.W.	$EURO_i$

Trade and Demand Elasticities

Import price elasticities by commodity	η_i^m
Canadian export price elasticities	ε_i^x
U.S. import price elasticities	ε_{ui}^m
R.O.W. import price elasticities	ε_{ri}^m

Ad Valorem Distortions (as percent of producer price)

Tariff rates by commodity and location of production for Canada and U.S.	$\phi_c^u, \phi_c^r, \phi_u^c, \phi_u^r$
Producer output subsidies	θ^o
Producer input subsidies (wages, capital, material, fixed costs)	$\theta^n, \theta^k, \theta^m, \theta^f$
Export taxes	τ^x
Export subsidies[1]	θ^x
Sales taxes on final demand	τ^f
Indirect taxes on materials use i in industry j	τ^m

Miscellaneous

Exogenous final supply of domestic good i	$EXFS_i$
Balance of Payments Deficit (1981$)	BOP
Domestic ownership share of industry i	Λ_i

Notes to Table 5.1

[1] In this version of model subsidies by U.S. of export sales to Canada is excluded.

5.3 Data Requirements

The basic data requirements consist of both benchmark product and income flows, plus extraneous estimates of structural parameters, such as trade elasticities, cost elasticities, and so forth. The data necessary for calibration, and read in as input to the TEST program is listed in Table 5.1. This data is not always available in a form directly suitable for input to a calibration program, and a large amount of work is involved in preparing the data. Preparation of basic input-output data, for example, is discussed in Appendix 1. The general framework in the preparation of this data set however, is that the benchmark commodity and industry aggregate flows must match those of the corresponding economic model with those exceptions noted in the last section. Similar remarks apply to the choice of relevant elasticities and ad valorem distortions; in all cases a matching of data at the appropriate aggregation level should be done as carefully as possible. For additional documentation on data construction the reader is referred to Binder I , Department of Finance, 1987, Special Studies.

In preparation of benchmark data, it is necessary to divide a value measure of product flows, into price and quantity components. Within GET the procedure is to set all domestic producer prices in the benchmark year to unity. In addition all foreign commodity flows are scaled by setting the border prices, after tariffs are applied, to unity. Thus we have base prices (domestic producer and border prices set equal to unity)

$$P_i^c = 1 \qquad \forall\ i \in \mathcal{M} \tag{3.1}$$

$$b_i^u\left(1+\phi_{ci}^u\right) = 1 \qquad \forall\ i \in \mathfrak{E} \tag{3.2}$$

$$b_i^r\left(1+\phi_{ci}^r\right) = 1 \qquad \forall\ i \in \mathfrak{E} \tag{3.3}$$

All observed flows are assumed to be valued at producer or border prices. This implies for example that in the data preparation, the value measure of final demand for a particular commodity, should not include sales or indirect taxes paid on the purchase.

Given the normalization of producer and border prices, all other prices are defined by the pricing identities of the model. Thus all consumer prices both of final consumers and intermediate consumers, are calculated by substituting (3.1)-(3.3) into the pricing identities of Table 2.3, using the values for the relevant model ad valorem distortion, and solving for the remaining prices. The prices solved for include

$$P^r, P^u,\ p^c, p^u, p^r, s^c, s^u, s^r, p_u^x, p_r^x.$$

The wage bill in value terms is read in as WB_j in industry j. The economy wide supply wage is set at 1.0. To compute total labour supply the producer wage in each industry j is set as

$$w_j = (1-\theta_j^n)w, \tag{3.4}$$

and then employment is measured in quantity units in industry j by

$$L_j = WB_j/w_j. \tag{3.5}$$

Aggregate employment, and hence labour supply, is given by

$$L = \Sigma_{j\in M} L_j. \tag{3.6}$$

Note that the measure of quantity in labour is constant base dollars of labour services, and not person years, or person-hours of employment. As labour is assumed to be perfectly substitutable between sectors unusually high or low wages in the base year in a given industry influences directly the calibrated measure of labour supply, both in that sector and hence in aggregate.

Having computed all benchmark prices, total output of domestic commodity i is defined by summing over all possible uses to give

$$X_i = \sum_{j\in M} YY_{ji}^c + D_i^c + E_i^u + E_i^r - XFS_i \tag{3.7}$$

Likewise total imports by region and commodity are defined by

$$M_i^u = \Sigma_{j\in M} YY_{ij}^u + D_i^u \tag{3.8}$$

$$M_i^r = \Sigma_{j\in M} YY_{ij}^r + D_i^r \tag{3.9}$$

Domestic final demand is defined as

$$F_i = D_i^c + E_i^u + E_i^r \tag{3.10}$$

Industry capital stocks and capital rentals or user costs (after subsidy) are read in respectively as K_j and r_j. Imputed private opportunity cost of capital services in industry j is thus defined as $r_jK_j = VK_j^T$. This will differ from income accruing to capital in sector j in the benchmark, which is calculated on a residual basis. Residual capital income less capital subsidies for base year by industry, VK_j^R, is[49]

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[49] It is possible to compute a capital stock on a residual basis as

$$K_j^R = VK_j^R/r_j$$

$$VK^R_j = \left(1+\theta^o_j\right)P^c_j\, X_j - WB_j - \Sigma_{i\in\mathcal{C}}\, s^c_{ij}YY^c_{ij} + s^\Gamma_{ij}YY^\Gamma_{ij} + s^\Gamma_{ij}YY^\Gamma \qquad (3.11)$$

5.4. Cost Function Approximations With Increasing Returns to Scale

Technology parameters are determined given the choice of functional forms described in chapter 2.4. Of particular importance is the manner in which the cost functions in the A and B industries are calibrated. As will be seen there is more than one alternative, depending upon the desired properties of the approximation. For the purposes of this section assume that there is a *true cost function* $AC^*(\circ)$, and the approximating cost function must be chosen from a particular class of functional forms. Choosing the parameters of the cost function in the model is basically an issue of the properties of the approximation, plus any restrictions placed on model structure given the functional form used.

The cost function used in the GET model, equation (4.5) chapter 2, is of the hyperbolic form, $TC = F + hy$ (an HBCF). (F is total fixed costs, and $h(w,r,P)$ is the marginal cost per unit output). This cost function is a restrictive functional form, but is extremely convenient to use. Standard industrial organization descriptive statistics for scale economies include minimum efficient scale (MES), defined to be that level of output at which average cost is within "x" per cent of minimum average cost. For the hyperbolic cost function, MES output, y_m is defined by the equation

$$AC\left(y_m\right) \equiv TC(y_m)/y_m = (1+x)h(w,r,P). \qquad (4.1)$$

x is usually taken as quite small, usually one per cent. Another common industrial organization scale economy summary statistic is the Cost-Disadvantage-Ratio (CDR)[50] which measures the proportion which average cost rises in going from MES to one-half MES. In the case of the Hyperbolic cost function case the definition of the CDR is amended to be the number s satisfying

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and thus an aggregate capital stock as

$$\bar{K}^R = \Sigma_{j\in\mathcal{M}}\, K^R_j\ .$$

This procedure, while common in the CGE literature, will be used only in the R and D industries.

[50] In the fortran coding of TEST the CDR is the variable LRSLOP. In many scale economy studies another statistic reported is the *extent of suboptimal capacity*, or the percentage of industry output produced in plants below MES. For further details on these measures and others, see Fuss and Gupta (1981) and Robidoux and Lester (1988).

$$AC\left(1/2\ y_m\right) = \frac{F}{1/2\ y_m} + h = (1+s)h(w,r,P). \qquad (4.2)$$

Thus in going from one-half MES to asymptotic minimum average cost, average costs fall by the CDR factor s. Given independent estimates of MES, CDR, and x in the case of a HBCF, then we have two equations.

$$\frac{F}{y_m} + h = (1+x)h \qquad (4.4)$$

$$\frac{F}{1/2\ y_m} + h = (1+s)h, \qquad (4.5)$$

which re-writing give two different expressions for fixed/variable cost ratios

$$F/h = xy_m \qquad (4.6)$$

$$F/h = 1/2\ sy_m \qquad (4.7)$$

Unless $x = 1/2\ s$ both (4.6) and (4.7) cannot hold simultaneously. This raises problems if one insists on a particular definition of MES. In practice s will be such that $1/2s > x$. Therefore one can choose a fixed/variable cost ratio F/h to lie in the interval $[xy_m, 1/2sy_m]$. The implications of taking the upper and lower bounds of this interval in order to approximate the "true" underlying cost function characterized by parameters (x, s, y_m) are now discussed.

Cost Function Approximation 1 $F/h = xy_m$

This approximation gives conservative values for cost savings achieved to a given increase in output. Given an x-per cent definition of MES, for $y = y_m$, it will provide an exact approximation to MES. The difficulty is that the implied CDR satisfies an exact relationship of $\hat{s} = 2x$. So if x is one per cent, the CDR is 0.02 which is an extremely mild form of scale economies. In terms of cost elasticities

$$\varepsilon(y) \equiv MC(y)/AC(y)$$

$$= \frac{h}{F/y+h} = \frac{1}{(F/h)/y+1}. \qquad (4.8)$$

In this case at 1/2 MES for x = 0.01

$$\varepsilon\ (0.5\ y_m) = \frac{1}{1.02}$$

$$= 0.980 \qquad (4.9)$$

which is an extremely low scale elasticity. At 1/2 MES the cost curve is extremely flat and little in the way of scale economies exist.

Cost Function Approximation 2 $F/h = 1/2sy_m$

This approximation has the feature that the approximating cost curve goes through the true cost function at one-half MES, but to actually achieve the cost savings achievable using the CDR, output must go well above the *true* MES output level. See figure 5.3 Using this approximation the fixed/variable cost ratio is higher. Suppose, for example, $s = 0.10$. Then in going from $1/2y_m$ to y_m costs decline by 5 per cent;

$$\frac{AC(y_m)}{AC(1/2y_m)} = \frac{1 + 0.5s}{1 + s} = \frac{1.05}{1.10} = 0.9545.$$

At the same time the cost elasticity is

$$\varepsilon(1/2y_m) = \left(\frac{1}{s+1}\right) = \frac{1}{1.10} = 0.91.$$

In this case however we get a conservative approximation to the true cost reduction over the interval $[1/2y_m, y_m]$. For true cost function, $AC^*(y)$, recall that by definition

$$\frac{AC^*(y_m)}{AC^*(1/2y_m)} = \frac{1}{1+s} = \frac{AC(y_m)}{AC(1/2y_m)} = \frac{1 + 1/2s}{1+s}$$

In the example the true cost reduction factor is 0.9091, versus the approximated cost reduction factor of 0.9545. The difficulty however is that the implied MES, $\hat{y}_m$, using a 1 per cent definition is much larger than the actual MES, y_m.

$$\frac{F}{h} = .01\hat{y}_m = 1/2sy_m,$$

so

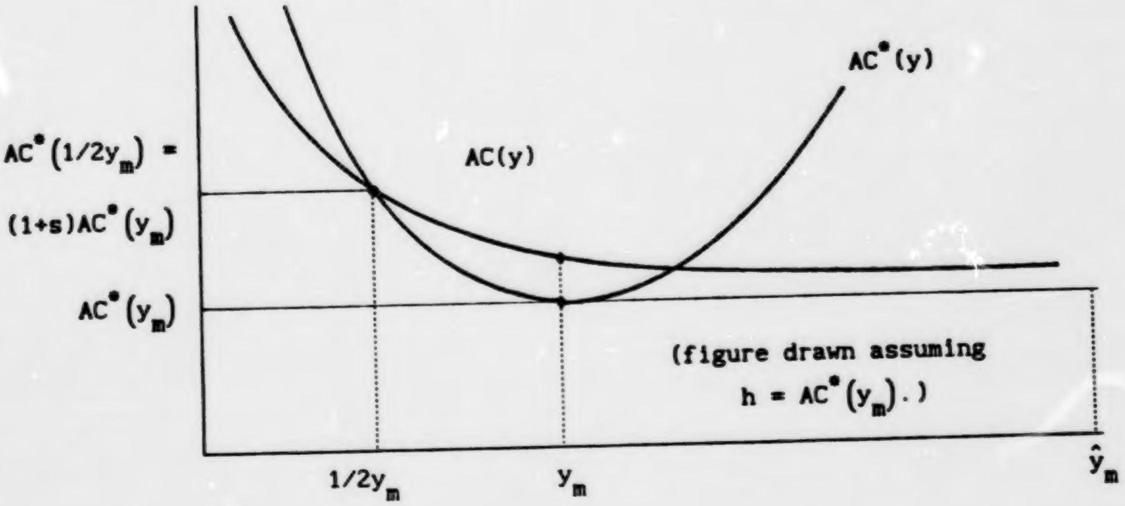
$$\hat{y}_m = \frac{.05}{.01}\, y_m = 5y_m.$$

Hence the MES implied by the HBCF is much larger than the actual data generated MES. The resulting approximate HBCF versus true average cost function is drawn in Figure 5.3. AC(y) is the HBCF approximating the true cost function.

Notice how the cost reduction over the range $(1/2y_m, y_m)$ from the approximate cost function is less than from the true, and the imputed MES output, $\hat{y}_m$, is much larger than the true.

Figure 5.3

Cost Function Approximation 3



For many purposes approximation 2 is preferred to approximation 1. With this approximation it should be kept in mind that a) cost reductions in the model achieved by output increases over the range from 0 to y_m will be understated, and b) model definitions of MES should not be taken seriously.

Cost Function Approximation 3 (Cost elasticity approach)

As has been shown, the key parameter in benchmarking an HBCF is the choice of the F/h ratio. An alternative procedure is to start with a cost elasticity ε^o, evaluated at some "appropriate" output level, y^o. Some scale studies provide ε^o directly and y^o might be chosen as either observed plant output, sample mean output, or perhaps one-half MES output. In any case the appropriate formulae for the fixed to variable cost ratio is

$$F/h = \left(\frac{1-\varepsilon^o}{\varepsilon^o}\right) y^o, \quad \varepsilon^o = \varepsilon^{COST} \tag{4.10}$$

For example, with $\varepsilon^o = 0.80$, $F/hy^o = 0.25$.[51]

Cost Function Approximation 4 (True cost savings approach)

The approximations used thus far have the difficulty that they do not give an accurate reflection of true cost reductions over the interval $\left[1/2y_m, y_m\right]$. An alternative approximation is as follows.

We start with the scale parameters y_m, s, observed output $\bar{y}$, and total cost TOT. Let a_L denote $AC^*(y_m)$ and $a_H \equiv AC^*(1/2y_m)$ denote cost levels on the true cost curve. Likewise, define

$$C_H = a_H \cdot y_m \tag{4.11}$$

$$C_L = a_L \cdot y_m \tag{4.12}$$

By definition $1+s = a_H/a_L$, so $C_H = (1+s)C_L$. With an HBCF we want to choose F and h to satisfy two constraints. First,

$$\frac{TOT}{\bar{y}} = \frac{F}{\bar{y}} + h; \tag{4.13}$$

i.e., the approximating cost function passes through the observed average cost-output point, with observed output $\bar{y}$. And second

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[51] This approximation procedure is used in Harris and McDonough (1987).

$$\frac{F}{1/2y_m} + h = (1+s)\left\{\frac{F}{y_m} + h\right\} \tag{4.14}$$

i.e. the approximating cost function yields a cost reduction of s/(1+s) over the interval $[1/2y_m, y_m]$.[52] Re-write (4.13) and (4.14) as

$$TOT = F + \bar{y}h \tag{4.15}$$

$$F = \left(\frac{s}{1-s}\right) hy_m \tag{4.16}$$

Solving (4.15) and (4.16) gives the solution values

$$\hat{F} = TOT - \bar{y}\hat{h} \tag{4.17}$$

$$\hat{h} = \frac{TOT}{\left(\frac{s}{1-s}\right)y_m + \bar{y}} \tag{4.18}$$

Note that the fixed/total cost ratio at y_m is $s/(1-s)$. Essentially equation (4.16) determines the F/h *ratio*, and then (4.17) is used to determine the levels of F and h consistent with observed costs.

Figure 5.4 illustrates approximation 4. Note that for the case illustrated, for output greater than y_m the approximating cost function overstates true cost reductions achievable. For this reason, it may be useful to amend the definition of costs by setting an upper bound on firm output at y_m. This will prevent the model from giving cost reductions which are not assumed to exist in the true cost function.[53]

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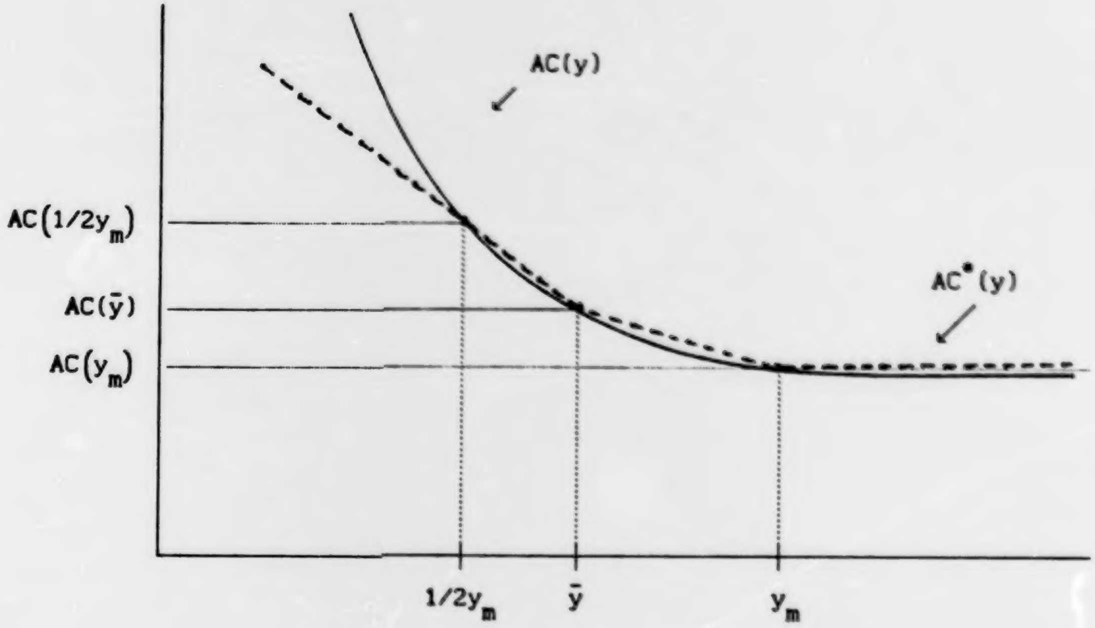
[52] These equations can be solved to give a fixed to variable cost ratio as,

$$F/hy_m = \left(\frac{s}{1-s}\right)$$

[53] Requiring $y \le y_m$ implies that marginal cost become vertical at MES output. In terms of the theory of chapter 2, this raises the possibility that it is optimal for firms to produce where $y = y_m$, which in turn implies that the pricing rules based on markup rules on marginal cost v, are no longer relevant. With a fixed number of firms this is a real possibility. Under free entry however an equilibrium with marginal cost in excess of v is impossible, since this would imply, except by accident, that profits were positive or negative. It is assumed that an equilibrium always occurs where marginal costs equal v. Algorithmic problems caused by bounding y from above are discussed in chapter 6.4.

Figure 5.4

Cost Function Approximation 4



Cost Function Approximation 5 (true cost savings using CSA)

The cost function approximation used in the current version of GET is a variant of approximation 4, but using a different measure of 'true cost savings'. In empirical estimates of scale economies in Canadian manufacturing Lester and Robidoux (1988) propose a measure they call CSA which is the reduction in average cost achieved by taking average industry output up to MES, expressed proportionately to observed average cost. Using the definition of CSA they define the coefficient c, as

$$c = [1/(1-CSA)] - 1 \qquad (4.19)$$

c measures the cost increase implied in the increase of observed average cost over MES average cost. The basic idea is similar to approximation 4. Equation (4.14) is replaced with

$$F / \bar{y} + h = (1+c)\{F/y_m + h\} \qquad (4.20)$$

Solving for $\hat{h}$ gives the equation

$$\hat{h} = \frac{TOT}{\bar{y} + [c/\{1/\bar{y} - (1+c)/y_m\}]} \qquad (4.21)$$

Fixed costs are calculated by equation (4.17). A diagram similar to 5.4 can be drawn except that the cost savings reproduced in the approximating cost function over the interval $[\bar{y}, y_m]$ are constrained to some ex ante value. This represents a considerable advantage over the other approximations. Consequently, approximation 5 is used to calibrate the cost function in the version of GET used in the Department of Finance.

5.4.2 Calibrating Fixed Capital and Labour

The approximation procedures described in the last section parameterize scale economies in the HBCF by setting a fixed to variable cost ratio at some output level, y. It remains to set the *levels* of fixed and variable costs, and at the same time calibrate the coefficients ω_{kj} and ω_{nj} of the fixed cost function (4.17), of chapter 2.

We first note that fixed costs can be divided into fixed capital costs, and fixed labour costs;

$$F = F_K + F_L$$

Furthermore variable costs per unit output, can be divided into material, capital and labour costs as

$$h = g(P) + v_K + v_L$$

F_K are fixed capital costs, F_L fixed labour costs, g(P) is unit material costs, and v_K and v_L are unit capital and labour costs respectively. The objective is to parameterize F_K and F_L. Let $\bar{y}$ denote the firm's observed output, T_K and T_L denote observed total payments to capital and labour.

Each of the approximation methods described determines a parameter z^{o}, such that

$$F = z^{o}h \tag{4.22}$$

Let $\ell^{o} \equiv T_L / T_K$ denote the observed labour-capital ratio in value terms. We assume initially

$$F_L / F_K = \gamma^{o}\ell^{o} \tag{4.23}$$

where γ^{o} is a parameter reflecting the difference between overall labour-capital ratio and the labour/capital ratio in fixed factors. The parameter γ^{o} is read into the calibration program and its construction is described in Robidoux (1986). In the absence of outside information on this parameter, analogous to the homotheticity assumption of conventional theory, one could set γ^{o} equal to one.[54] Using (4.22) and (4.23) gives

$$F_K + F_L = z^{o}\left(g + v_K + v_L\right) \tag{4.24}$$

or

$$\bar{y}F_K + \bar{y}F_L = z^{o}\left(g\bar{y} + v_K\bar{y} + v_L\bar{y}\right) \tag{4.25}$$

since $F_L = \gamma^{o}\ell^{o}F_K$ and $T_K = F_K + v_K y$, we get

$$F_K = \frac{z^{o}TOT}{\left(y+z^{o}\right)\alpha^{o}} \tag{4.26}$$

$$F_L = \gamma^{o}\ell^{o}F_K \tag{4.27}$$

where

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[54] Setting γ^{o} equal to one does not actually result in a homothetic cost function overall; with fixed costs it is impossible to have a production function which is homothetic in all factors. Furthermore given changes in the wage-rental ratio, the initial capital-labour ratio in variable costs will change from the ratio prevailing in fixed costs.

$$TOT = g\bar{y} + T_K + T_L$$

$$\alpha^o \equiv 1 + \gamma^o \ell^o.$$

Total costs in the benchmark, are defined as total opportunity costs (using the user cost price of capital services) divided by the number of firms. Thus in industry j for example

$$TOT_j = (\Sigma_{i \in G} YY^c_{ij} + YY^u_{ij} + YY^r_{ij} + WB_j + r_j K_j)/\nu_j. \tag{4.28}$$

In some instances the target fixed/variable cost ratio, z^o, will be inconsistent with the basic observed data, given the requirement that fixed costs consist only of capital and labour costs and the fixed cost labour/capital ratio satisfy (4.20). With this in mind the maximum feasible F/h ratio, z^{max}, assuming $\gamma^o \le 1$, is defined, setting $F_K = T_K$, by the equation

$$\begin{aligned} z^{max} &= \frac{Fy}{hy} \\ &= yF/TOT - F_K - F_L \qquad (4.29) \\ &= y\alpha^o T \;/\; \left(TOT - \alpha^o T_K\right) \end{aligned}$$

If $z^{max} < z^o$, then the target fixed-variable cost ratio cannot satisfy the observed data. One procedure to follow in this case would be to set $z^o = z^{max}$ and then set

$$\left.\begin{aligned} F_K &= T_K \\ F_L &= \gamma^o \ell^o T_K \\ v_K &= 0 \\ v_L &= \left(T_L - \gamma^o \ell^o T_K\right) \ge 0. \end{aligned}\right\} \tag{4.30}$$

Notice that all relevant non-negativity conditions on F_K, F_L, v_K, v_L are met by (4.30). In the case of $z^o < z^{max}$ it is easy to verify that $F_K < T_K$ and $F_L < T_L$. In fact (4.26) describing F_K as a function of z can be shown to have the properties that $F_K(0) = 0$, F_K strictly increasing on $\left(0, z^{max}\right)$, and $F_K\left(z^{max}\right) = T_K$.

Using approximation 4 or 5 poses additional problems in calibrating fixed versus variable capital. Since the levels of F and h are given, we must have

$$\hat{F} = F_K + F_L$$

$$\hat{h} = g(P) + v_K + v_L$$

The observed data satisfies

$$\hat{F} + \bar{y}\hat{h} = TOT = g\bar{y} + T_K + T_L.$$

Using the fixed labour/capital ratio in (4.27) we have

$$\hat{F} = \alpha^o F_K, \quad \text{with} \quad \alpha^o \quad \text{computed with} \quad z^o = \left(\frac{s}{1-s}\right) y_m$$

or

$$F_K = \hat{F}/\alpha_o. \tag{4.31}$$

Provided $F_K \le T_K$ this solution will be satisfactory, with

$$v_K = \left(T_K - F_K\right) / \bar{y} \tag{4.32}$$

and

$$\begin{aligned} F_L &= \gamma^o \ell^o F_K \\ v_L &= \left(T_L - F_L\right) / \bar{y} \end{aligned} \tag{4.33}$$

The problem with this procedure occurs if $F_K > T_K$. In this case, allocating all of existing capital and labour to fixed factors is not sufficient to yield the solution fixed costs from (4.17). In this case the recommended procedure is to set, $F_K = T_K$, $F_L = \gamma^o \ell^o F_K$, with $v_K = 0$ and v_L given by (4.33).

For calibration purposes, it is now possible to convert total factor services into fixed and variable components. Thus we can define the fixed cost parameters by

$$\omega_{nj} = F_K/r_j$$

$$\omega_{kj} = F_L/w_j.$$

Likewise the industry total *variable* labour and capital payments (and quantities) in the A and B industries are given by

$$VLV_j = v_{Lj}\,\bar{y}_j \qquad \left(L_j^v = VLV_j/w_j\right) \tag{4.34}$$

and

$$VKV_j = v_{Kj}\,\bar{y}_j. \qquad \left(K_j^v = VKV_j/r_j\right). \tag{4.35}$$

5.5 Input-Output Matrices

Implicit in the benchmark intermediate product flows and intermediate imported inputs is a set of input-output matrices, A^c, A^u, and A^r. The coefficients in these matrices are given by

$$a_{ij}^c = YY_{ij}^c/X_j \tag{5.1}$$

$$a_{ij}^u = YY_{ij}^u/X_j \tag{5.2}$$

$$a_{ij}^r = YY_{ij}^r/X_j \tag{5.3}$$

Similarly on the primary input side, variable input requirements coefficients are given by

$$a_{nj} = L_j^v/X_j \tag{5.4}$$

$$a_{kj} = K_j^v/X_j \tag{5.5}$$

5.6 Utility Function and Final Domestic Expenditure Parameters

In this section the calibration of the final demand function parameters is detailed. It is first necessary to construct a definition of income for final expenditure by domestic agents in the benchmark equilibrium. This is defined simply as the sum of expenditure on final domestic demand and imports for final consumption at consumer prices.

$$I^c = \Sigma_{j\in\mathcal{G}}\; p_i^c D_i^c + p_i^u D_i^u + p_i^r D_i^r \tag{6.1}$$

Expenditure share parameters in the utility function (equation 3.1, chapter 2) are calibrated by

$$\mu_i = \frac{p_i^c D_i^c + p_i^u D_i^u + p_i^r D_i^r}{I^c} \tag{6.2}$$

Note $D_i^c = 0$ for $i \in E$. Define the *domestic expenditure share* parameter within commodity i category as

$$S_i^c = \frac{p_i^c D_i^c}{p_i^c D_i^c + p_i^u D_i^u + p_i^r D_i^r} \tag{6.3}$$

Likewise the US and ROW shares are defined analogously, S_i^u, S_i^r. The next step is to calibrate the Armington substitution elasticities in the utility function. Let η_i^m denote the import price elasticity. Then

$$\sigma_i = \frac{-\eta_i^m - 1 + S_i^D}{S_i^D} \tag{6.4}$$

is the Armington substitution elasticity. Consistency requires that $\sigma_i > 1$ for all i.

The final set of utility function parameters to be calibrated are the share coefficients within the CES-Armington aggregators. From the properties of the demand functions (3.3-3.5, chapter 2) it can be shown that the following relationships must hold between ratios of expenditure shares;

$$\frac{S_i^c}{S_i^u} = \frac{{\delta_i^c}^{\sigma_i} \, {p_i^c}^{\left(1-\sigma_i\right)}}{{\delta_i^u}^{\sigma_i} \, {p_i^u}^{\left(1-\sigma_i\right)}} \; ; \qquad \frac{S_i^r}{S_i^u} = \frac{{\delta_i^r}^{\sigma_i} \, {p_i^r}^{\left(1-\sigma_i\right)}}{{\delta_i^u}^{\sigma_i} \, {p_i^u}^{\left(1-\sigma_i\right)}} \tag{6.5}$$

Noting that the shares must sum to one, (6.5) provides two restrictions on two unknowns, $\delta_i^c$and δ_i^r. These equations can a be written as

$$\frac{\delta_i^c}{\delta_i^u} = \left(\frac{S_i^c}{S_i^u}\right)^{\left(\frac{1}{\sigma_i}\right)} \left(\frac{p_i^c}{p_i^u}\right)^{\left(\frac{\sigma_i - 1}{\sigma_i}\right)} \; ; \qquad \frac{\delta_i^r}{\delta_i^u} = \left(\frac{S_i^r}{S_i^u}\right)^{\left(\frac{1}{\sigma_i}\right)} \left(\frac{p_i^c}{p_i^u}\right)^{\left(\frac{\sigma_i - 1}{\sigma_i}\right)} \tag{6.6}$$

which can be re-written as

$$\delta_i^c = \delta_i^u \, \lambda_1 \tag{6.7}$$

$$\delta_i^r = \delta_i^u \, \lambda_2. \tag{6.8}$$

One can choose an arbitrary normalization on the δ_i coefficients as demands are homogeneous of degree 0 in $\left(\delta_i^c, \ \delta_i^u, \ \delta_i^r\right)$. The most convenient normalization is

$$\delta_1^c + \delta_1^u + \delta_1^r = 1.0 \tag{6.9}$$

So substituting gives the equations

$$\delta_1^c = \left(1 - \delta_1^c - \delta_1^r\right) \lambda_1 \tag{6.10}$$

$$\delta_1^r = \left(1 - \delta_1^c - \delta_1^r\right) \lambda_2 \tag{6.11}$$

Solving for the unknowns $\left(\delta_1^c, \delta_1^r\right)$ yields[55]

$$\delta_1^c = \frac{\lambda_1}{\left(1+\lambda_1\right)\left(1+\lambda_2\right) - \lambda_1\lambda_2} \tag{6.12}$$

$$\delta_1^r = \frac{\lambda_2}{\left(1+\lambda_1\right)\left(1+\lambda_2\right) - \lambda_1\lambda_2} \tag{6.13}$$

5.7 Factor Demands Unit Cost Function Parameters

This section describes the calibration of the unit cost function parameters in all domestic industries. Within the A and B industry groups recall that the unit cost function refers to the marginal cost function and not average cost. By Shepherd's lemma the derivative of the unit cost function with respect to a price gives the demand for a factor of production per unit output, provided that demand is sensitive to output changes. Factor demands derived from fixed costs are not related to the derivatives of the unit cost function.

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[55] Note: in TEST the code uses share parameters in primal form:

$$SHRC_1 = \delta_1^c$$

$$SHRUS_1 = \delta_1^u$$

$$SHRO_1 = \delta_1^r.$$

On duality and functional form in the CES case the reader is referred to Varian (1987), chapter 3. pp.30-32.

First, some necessary accounting. Compute total factor payments, $FACT_i$, (exclusive of fixed cost factors)for industry i as

$$FACT_j = \Sigma_{i\in\mathcal{G}} s^c_{ij} YY^c_{ij} + s^u_{ij} YY^u_{ij} + s^r_{ij} YY^r_{ij} + VLV_j + VKV_j \tag{7.1}$$

Unit cost in the benchmark for A and B industries is given by

$$v_i = FACT_i/X_i \tag{7.2}$$

Within the R and D industries unit cost functions are scaled under the assumption of zero economic profits, or price equal average cost in these industries. An important implication of this procedure is that capital stock is computed on a residual basis in these industries. Hence

$$v_i = \left(1 + \theta^o_i\right) P^c_i \quad i \in R \cup D. \tag{7.3}$$

In order to calibrate the parameters of the Cobb-Douglas unit cost function it is necessary to first define some preliminary variables. Total material cost i within industry j is defined as

$$Mat_{ij} = s^c_{ij} YY^c_{ij} + s^r_{ij} \; YY^u_{ij} + s^r_{ij} YY^r_{ij} \tag{7.4}$$

The within-group i share parameters of the cost function are

$$\beta^c_{ij} = s^c_{ij} YY^c_{ij}/Mat_{ij} \tag{7.5}$$

$$\beta^u_{ij} = s^u_{ij} YY^u_{ij}/Mat_{ij} \tag{7.6}$$

$$\beta^r_{ij} = s^r_{ij} YY^r_{ij}/Mat_{ij}. \tag{7.7}$$

The share parameter on material aggregate i in industry j is

$$\alpha_{ij} = Mat_{ij}/v_jX_j \qquad i \in \mathcal{G}, \quad j \in \mathcal{M}. \tag{7.8}$$

The share coefficients on variable labour and capital are

$$\left.\begin{aligned} \alpha_{nj} &= VLV_j/v_jX_j \\ \alpha_{kj} &= VKV_j/v_jX_j \end{aligned}\right\} j \in \mathcal{M} \tag{7.9}$$

Having computed these parameters a simple check on the calibration is to verify

$$\Sigma_{i\in\mathcal{G}} \alpha_{ij} + \alpha_{nj} + \alpha_{kj} = 1.0 \quad \forall\ j \in \mathcal{M}. \tag{7.10}$$

The constant in the unit cost function, γ_{oj}, must be chosen so that computed cost equals unit cost as given by the scaling of producer prices in the case of R and D industries (equation 7.3) and in the case of A and B industries the unit cost must equal v_j as given by (7.2). Hence

$$\gamma_{oj} = \log v_j - \Sigma_{j\in\mathcal{G}} \alpha_{ij} \log \Gamma_{ij} - \alpha_{nj} \log w_j - \alpha_{kj} \log r_j \tag{7.11}$$

with

$$\log \Gamma_{ij} = \beta^c_{ij} \log s^c_{ij} + \beta^u_{ij} \log s^u_{ij} + \beta^r_{ij} \log s^r_{ij} \tag{7.12}$$

where Γ_{ij} is the price index of material aggregate i within industry j.

5.8. Calibration of Export Demand Function Parameters

In this section we describe the derivation of the export demand functions by U.S. and ROW residents for Canadian goods. We begin by deriving the U.S. export demands from an explicit utility function. We then derive export equations for R.O.W. using the same functional form for the underlying utility function. In the latter case however a slightly different calibration procedure is used due to data constraints.

5.8.1 U.S. Export Demand Functions

As described in chapter 2.3. the U.S. aggregate consumer has a Cobb-Douglas aggregator over all expenditure categories, and a CES Armington aggregator over domestic, ROW, and Canadian goods. Utility maximization by the aggregate U.S. 'consumer' results in demand functions for Canadian produced goods, which are the export demand functions of the GET model. Recall that the U.S. CES aggregator in commodity category i is in primal form

$$C^u_i = \left[\psi^u_{ic}\left(X^u_{iu}\right)^{\rho^u_i} + \psi^u_{iu}\left(X^u_{iu}\right)^{\rho^u_i} + \psi^u_{ir}\left(X^u_{ir}\right)^{\rho^u_i} \right]^{1/\rho^u_i} \tag{8.1}$$

where X^u_{iu}, X^u_{ic} and X^u_{ir} are respectively the quantities of the U.S., the Canadian and R.O.W. ith good purchased by the U.S. and $\sigma^u_i = 1-1/\rho^u_i$ is the Armington elasticity of substitution. ψ^u_{ic}, ψ^u_{iu} and ψ^u_{ir} are distribution parameters. Solving the representative consumer's utility maximization problem yields the following commodity demand functions for U.S. consumers:

$$X_{ic}^{u} = \frac{\left(I_{i}^{u}\right)\left(\psi_{ic}^{u}\right)^{\sigma_{i}^{u}} q_{ic}^{u\,(-\sigma_{i}^{u})}}{\left[\left(\psi_{iu}^{u}\right)^{\sigma_{i}^{u}}\left(q_{iu}^{u}\right)^{(1-\sigma_{i}^{u})} + \left(\psi_{ic}^{u}\right)^{\sigma_{i}^{u}}\left(q_{ic}^{u}\right)^{(1-\sigma_{i}^{u})} + \left(\psi_{ir}^{u}\right)^{\sigma_{i}^{u}}\left(q_{ir}^{u}\right)^{(1-\sigma_{i}^{u})}\right]} \tag{8.2}$$

$$X_{iu}^{u} = \frac{\left(I_{i}^{u}\right)\left(\psi_{iu}^{u}\right)^{\sigma_{i}^{u}} q_{iu}^{u\,(-\sigma_{i}^{u})}}{\left[\left(\psi_{iu}^{u}\right)^{\sigma_{i}^{u}}\left(q_{iu}^{u}\right)^{(1-\sigma_{i}^{u})} + \left(\psi_{ic}^{u}\right)^{\sigma_{i}^{u}}\left(q_{ic}^{u}\right)^{(1-\sigma_{i}^{u})} + \left(\psi_{ir}^{u}\right)^{\sigma_{i}^{u}}\left(q_{ir}^{u}\right)^{(1-\sigma_{i}^{u})}\right]} \tag{8.3}$$

$$X_{ir}^{u} = \frac{\left(I_{i}^{u}\right)\left(\psi_{ir}^{u}\right)^{\sigma_{i}^{u}} q_{ir}^{u\,(-\sigma_{i}^{u})}}{\left[\left(\psi_{iu}^{u}\right)^{\sigma_{i}^{u}}\left(q_{iu}^{u}\right)^{(1-\sigma_{i}^{u})} + \left(\psi_{ic}^{u}\right)^{\sigma_{i}^{u}}\left(q_{ic}^{u}\right)^{(1-\sigma_{i}^{u})} + \left(\psi_{ir}^{u}\right)^{\sigma_{i}^{u}}\left(q_{ir}^{u}\right)^{(1-\sigma_{i}^{u})}\right]} \tag{8.4}$$

where I_i^u is a constant defining units of measurement and q_{iu}^u, q_{ic}^u and q_{ir}^u are respectively prices of U.S., Canadian and R.O.W. commodities.

Since X_{ic}^u and X_{ir}^u are respectively the demands for Canadian and R.O.W. from U.S. consumers, equation (8.2) is the relevant export demand equation. Hence $X_{ic}^u = E_i^u$.

Given an a priori value of the Armington elasticity σ_i^u, equations (8.2) and (8.4) can be used to solve for the distribution parameters as follows:

$$\left(\frac{q_{iu}^{u}}{q_{ij}^{u}}\right)^{\left(1-\sigma_{i}^{u}\right)/\sigma_{i}^{u}} \left(\frac{S_{ij}^{u}}{S_{iu}^{u}}\right)^{\left(1/\sigma_{i}^{u}\right)} = \left(\frac{\psi_{ij}^{u}}{\psi_{iu}^{u}}\right) \tag{8.5}$$

where S_{ij}^u is the fraction of U.S. expenditures on commodity i accounted for by imports from country j and S_{iu}^u is the share of the U.S. expenditures which is satisfied by U.S. production.[56] The computed share parameters can be normalized such that:

$$\psi^u_{ic} + \psi^u_{iu} + \psi^u_{ir} = 1.0 \tag{8.6}$$

Having calculated the distribution parameters we can find the calibration value of I^u_i using one of the export demand equations.

Most of the data needed to calibrate the U.S. export demand equations for Canadian goods are available in the GET databank:

q^u_{ic}: Consumption price of Canada supplied good i to the U.S. (QUC)

q^u_{iu}: Consumption price of U.S. supplied good i to the U.S. (QUU)

q^u_{ir}: Consumption price of R.O.W. supplied good i to the U.S. (QUR)

σ^u_i : Armington elasticity of substitution in U.S. commodity i consumption aggregator (SIGMAU)

X^u_{ic}: Export of Canadian commodity i to the U.S. (EUS)

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[56] The value of the elasticity of substitution σ^u_i may or may not be computed directly within the calibration program. If U.S. price elasticities of import demand for Canadian goods are used (η^m_i) then the parameter σ^u_i is given by

$$\sigma^u_i = \frac{\eta^m_i + S^u_{ic}}{-\left(1 - S^u_{ic}\right)} \tag{N.8.1}$$

This import price elasticity which is particular to Canadian imports into the U.S., does not always conform to more conventional import price elasticities which refer to *all* imports; denote this latter price elasticity by η^M_i. Using this elasticity the calibrated value for σ^u_i is given by

$$\sigma^u_i = \frac{\eta^M_i + S^m_i}{-(1 - S^m_i)} \tag{N.8.2}$$

where S^m_i is the aggregate share of the domestic U.S. market accounted for by imports from all regions.

S^u_{ic}: Share of total U.S. expenditures on commodity i accounted for by imports from Canada (IPRC)

S^u_{ir}: Share of total U.S. expenditures on commodity i accounted for by imports from R.O.W. (IPRR)

S^u_{iu}: Share of total U.S. expenditures on commodity i accounted for by U.S. production (IPRU)

The three last variables have been constructed using different data sources and the interested reader should refer to Robidoux (1986). The shares can be constructed using import-export data, from either Statistics Canada or DRI (U.S.). Depending on the sources for the numerator and the denominator, three different ratios can be calculated for each share.

5.8.2 R.O.W. Export Demand Functions

The derivation of R.O.W. export demand equations follows the same scheme as the solution of the U.S. utility maximization problem. However the solution for the coefficients $\left(\psi^r_{ic}, \psi^r_{iu}, \psi^r_{ir}\right)$ is different since we cannot get estimates of the R.O.W. consumption shares by CHM commodity. In light of this a slightly different calibration procedure for R.O.W. export demand equations will be used.

The resulting R.O.W. export demand equation for U.S. and Canadian produced commodity i are:

$$X^r_{iu} = \frac{\left(I^r_i\right)\left(\psi^r_{iu}\right)^{\sigma^r_i}\left(q^r_{iu}\right)^{-\sigma^r_i}}{\left[\left(\psi^r_{iu}\right)^{\sigma^r_i}\left(q^r_{iu}\right)^{\left(1-\sigma^r_i\right)} + \left(\psi^r_{ic}\right)^{\sigma^r_i}\left(q^r_{ic}\right)^{\left(1-\sigma^r_i\right)} + \left(\psi^r_{iu}\right)^{\sigma^r_i}\left(q^r_{iu}\right)^{\left(1-\sigma^r_i\right)}\right]} \tag{8.7}$$

$$X^r_{ic} = \frac{\left(I^r_i\right)\left(\psi^r_{ic}\right)^{\sigma^r_i}\left(q^r_{ic}\right)^{-\sigma^r_i}}{\left[\left(\psi^r_{iu}\right)^{\sigma^r_i}\left(q^r_{iu}\right)^{\left(1-\sigma^r_i\right)} + \left(\psi^r_{ic}\right)^{\sigma^r_i}\left(q^r_{ic}\right)^{\left(1-\sigma^r_i\right)} + \left(\psi^r_{ir}\right)^{\sigma^r_i}\left(q^r_{ir}\right)^{\left(1-\sigma^r_i\right)}\right]} \tag{8.8}$$

The elasticity of substitution σ^r_i is calibrated using the import price elasticity, on alternatively export price elasticities.[57] The problem is to benchmark the constant I_i^r, and the share parameters ψ_{iu}^r, ψ_{ic}^r, ψ_{ir}^r. We can simplify the notation by re-writing a typical pair of R.O.W. export demand equations from R.O.W. as

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[57] See the previous footnote.

$$X_u^r = I\lambda_u q_u^{-\sigma} / \left(\lambda_u q_u^{(1-\sigma)} + \lambda_c q_c^{(1-\sigma)} + \lambda_r q_r^{(1-\sigma)} \right) \tag{8.9}$$

$$X_c^r = I\lambda_c q_c^{-\sigma} / \left(\lambda_u q_u^{(1-\sigma)} + \lambda_c q_c^{(1-\sigma)} + \lambda_r q_r^{(1-\sigma)} \right) \tag{8.10}$$

The notation is reasonably obvious.[58] Notice that (8.9) and (8.10) are homogeneous of degree 0 in the coefficients $(\lambda_u, \lambda_c, \lambda_r)$.

It is convenient to impose a linear normalization on these parameters so that benchmark data/parameter set satisfy

$$\lambda_u q_u^{(1-\sigma)} + \lambda_c q_c^{(1-\sigma)} + \lambda_r q_r^{(1-\sigma)} = 1.0 \tag{8.11}$$

with this normalization (8.9) and (8.10) become

$$X_u^r = I\lambda_u q_u^{-\sigma} \tag{8.12}$$

$$X_c^r = I\lambda_c q_c^{-\sigma} \tag{8.13}$$

We now have four parameters values, I, λ_c, λ_u, λ_r to satisfy three equations (8.11), (8.12) and (8.13). Recall X_u^r, X_c^r, q_u, q_c, q_r and σ are all given at this point. We have therefore one degree of freedom in choosing these parameter values. A convenient choice at this point is to normalize the sum of λ_u and λ_c. In particular set

$$\lambda_c + \lambda_u = 0.2 \tag{8.14}$$

The economic interpretation of (8.14) is that Canada and the U.S. goods jointly account for 20 percent of R.O.W. consumption. This interpretation however is entirely spurious; the important point is that λ_c, λ_u be positive, and the solution value for λ_r in (8.11) also be positive. Using (8.12), (8.13) and (8.14) the solution for I is given by

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[58] For example in GET code the "share" coefficient $\lambda_u = \left(\psi_u^u\right)^{\sigma^r}$ would correspond to RODUS(I) * * SIGMAR(I) and I to AYRO(I), etc.

$$\hat{I} = \left(X_u^r q_u^\sigma + X_c^r q_c^\sigma\right) / 0.2 \qquad (8.15)$$

where $\wedge$ denotes the solution value. The solution for λ_u and λ_c is

$$\hat{\lambda}_u = X_u^r q_u^\sigma / \hat{I} \qquad (8.16)$$

$$\hat{\lambda}_c = X_c^r q_c^\sigma / \hat{I} \qquad (8.17)$$

Given (8.16) and (8.17), use (8.11) to solve for $\hat{\lambda}_r$. We have to check that the solution value $\hat{\lambda}_r$ is positive.

This calibration procedure means we need data only on U.S. exports to R.O.W. and Canadian exports to R.O.W. The drawback is that in this case the constant term $\hat{I}$ cannot be interpreted as an accurate measure of total R.O.W. consumption of the commodity in question. For the purposes of the GET model this poses no difficulties.

The data needed to calibrate the R.O.W. export demand equations are the following:

q_{ic}^r: Consumption price of Canadian supplied good to R.O.W. (QRC)

q_{iu}^r: Consumption price of the U.S. supplied good to R.O.W. (QRU)

q_{ir}^r: Consumption price of the R.O.W. supplied good in R.O.W. (QRR)

σ_i^r : Armington elasticity of substitution in R.O.W. commodity i consumption aggregator (SIGMAR)

X_c^r : Value of exports of Canadian commodity i to R.O.W. (ERO)

X_u^r : Value of exports of U.S. commodity i to R.O.W. (EURO)

The value of Canadian and U.S. exports to R.O.W. are computed from Statistics Canada. Once again the reader should refer to Robidoux (1986) for more details on data construction.

5.9 Calibration of Conjectural Variation in Pricing Rules

As discussed in section 2 of this chapter, the pricing rules within the A industries use conjectural variation coefficients as amended by the basic markup implied by the pricing theory. The conjectural variations are chosen so as to be consistent with target price equal average cost, computed at benchmark actual prices.

Under MCH pricing it is necessary to compute a market elasticity of demand in the benchmark as described in section 2.7, chapter 2, as a weighted average of intermediate, final and export demand. To get an intermediate materials demand elasticity start by taking an assumed value for perceived elasticity of demand for domestic material i in industry j, ε^{m}_{ij}. By conventional calculation this gives an implied relationship between the perceived intermediate factor substitution elasticity and ε^{m}_{ij},

$$\hat{\sigma}_{ij} = \varepsilon^{m}_{ij} \Big/ \left\{-1 + \left(\frac{\alpha_{ij}\beta_{ij}}{\nu_j} - 1\right)\right\} \tag{9.1}$$

Export demand elasticities are

$$\varepsilon^{xu}_{i} = -\sigma^{u}_{i} - \left(1-\sigma^{u}_{i}\right) \frac{q^{u}_{ic}E^{u}_{i}}{I^{u}_{i}} \tag{9.2}$$

$$\varepsilon^{xr}_{i} = -\sigma^{r}_{i} - \left(1-\sigma^{r}_{i}\right) \frac{q^{r}_{ic}E^{r}_{i}}{I^{r}_{i}} \tag{9.3}$$

The market elasticity of demand is computed by weighting each individual elasticity by the respective share of the total output accounted for by demand from the particular source. Thus the market price elasticity is

$$\varepsilon^{m}_{i} = \varepsilon^{d}_{i}\left(\frac{D^{c}_{i}}{X_{i}}\right) + \varepsilon^{xu}_{i}\left(\frac{E^{u}_{i}}{X_{i}}\right) + \varepsilon^{xr}_{i}\left(\frac{E^{u}_{i}}{X_{i}}\right) + \sum_{j \in M} \frac{a^{c}_{ji}X_{j}}{X_{i}}\,\varepsilon^{m}_{ij} \tag{9.4}$$

Economic theory requires that the absolute value of the elasticity be greater than one. Thus a lower boundary on ε^{m}_{i} is set as

$$\left|\varepsilon^{m}_{i}\right| \geq \underline{\varepsilon}. \tag{9.5}$$

Industries for which this constraint is binding, must be interpreted as having a perceived elasticity no less than some minimum value, even if the actual elasticity is less. Using this elasticity an unadjusted monopoly pricing gross markup in A industries is computed;[59]

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[59] The derivation of this formulae follows from the first-under condition for monopoly profit maximization. Let D(q) be the (inverse) demand curve and c (constant) marginal cost. Then with an ad valorem producer subsidy θ, based on the selling price $P = D(Q)$ profit is

$$\pi = D(Q)(1 + \theta)Q - cQ.$$

The F.O.C. imply $MR = \left(\frac{1}{1+\theta}\right)c$, or $P\left(1 + \frac{1}{\varepsilon^{m}}\right) = \left(\frac{1}{1+\theta}\right)c$, from which (9.6) is derived.

$$\Delta_i^M = \frac{-\varepsilon_i^m}{\left(-\varepsilon_i^m - 1\right)\left(1 + \theta_i^o\right)} \tag{9.6}$$

As discussed in chapter 2.7 the pure Eastman-Stykolt markup is given by

$$\Delta_i^{ES} = \frac{\left(1 + \phi_{ic}^u\right)b_i^u}{v_i} \tag{9.7}$$

Given a pricing weight of λ_i on ESH pricing, and $(1-\lambda_i)$ on MCH pricing the unadjusted gross markup of producer price on unit cost is

$$\hat{\Delta}_i = \lambda_i \Delta_i^{ES} + \left(1-\lambda_i\right)\Delta_i^M \tag{9.8}$$

The actual bench gross markups for A and B industries are

$$\Delta_i^{\#} = \left(\frac{1.0}{v_i}\right) \tag{9.9}$$

The *zero profit* gross markups are

$$\Delta_i^{*} = AC_i/v_i \tag{9.10}$$

Depending upon the calibration method the cv's can be calibrated such that the pricing rule used produces upon impact either the producer prices of the benchmark, or the average costs of the benchmark. The computed "conjectural variation" for A industries, cv_i, are chosen to satisfy either

$$\Delta_i^{*} = cv_i\hat{\Delta}_i \qquad i\epsilon A \quad \text{(average cost calibration)} \tag{9.11}$$

or

$$\Delta_i^{\#} = cv_i\hat{\Delta}_i \qquad i\epsilon A \quad \text{(producer price calibration)} \tag{9.12}$$

Which of these two methods is used depends upon the objectives of the calibration as discussed in section 2. The model is currently calibrated using the average cost calibration of cv's.

5.10 Budget Constraints and Endowment Calibration

In the benchmark data set, which can be thought of as approximately a *quasi-equilibrium* of the GET model, income from all sources must be sufficient to purchase demands, on the part of the aggregate domestic spending agent. *Income* in the benchmark is the sum of

1) sales of labour services
2) pure economic profits received through ownership of domestic industry
3) net government lump-sum transfers
4) capital income endowment
5) transfers from foreigners.

6) sales of exogenous final supplies.

Items 1-3 and 6 are implicit within the benchmark data set itself. And can be computed in a straightforward fashion. Thus given model distortions in ad valorem form, and benchmark data, implied net government revenue from distortions or transfers to non-government spending agents, GOV, is given simply by equations (5.7)-(5.16) of chapter 2. Likewise aggregate profits accruing to domestic non-government spenders is Agprof, as given by equation (5.6) of chapter 2. The value of sales of exogenous final supply, VXS is

$$VXS = \Sigma_{i \in M} P^c_i \, XFS_i \tag{10.1}$$

Exogenous final supplies which appear in the benchmark reflect unusual changes in inventories. For some commodities inventory draw-downs were sufficiently large as to produce negative final demand. In the base equilibrium the income from these inventory sales is excluded assuming that in the long run inventory investment would return to the average pattern.

Within the benchmark the transfers from foreigners reflect disequilibrium in the balance of payments. In choosing a measure of disequilibrium one is making an implicit assumption as to what a *normal* long run situation might be. The assumption adopted in the calibration of GET is that the observed current account surplus or deficit is not sustainable on a long run basis; The deficit of the benchmark year is treated as an exogenous transfer from foreigners to domestic spending agents. In the event that this transfer were not present income available for spending would be reduced by the same amount.[60] Let DKY denote exogenous domestic "capital" income. Given the income-expenditure identity it must be the case that

$$I^c = w\,L + Agprof + BOP + DKY + VXS \tag{10.2}$$

Given that I^c, expenditure is observed in the benchmark, and items 1-3 and 5-6 are given, capital endowment income must be such that (10.2) holds, or alternatively the capital endowment of domestic spenders is calibrated such that they have just enough income to purchase the benchmark consumption bundle. This endowment is subsequently treated as exogenous in doing policy counterfactuals.

Obviously calibration errors are introduced through incorrect measurement of any of the sources of income. Given that the capital income endowment is determined residually, these errors will show up in this component directly. Some comment is called for on the nature of the BOP variable. A criticism one could make would be that in a fast growing economy, with large capital inflows, one would expect to observe a current account deficit, independent of whether the monetary authorities were saving or dissaving on behalf of the country by inducing (passively or otherwise) changes in foreign exchange reserves. What would then be an appropriate long run calibration for such an economy? Whalley (1985) treats these capital flows as exogenous, and thus focuses on changes in trade patterns holding the existing pattern of capital flows constant. This does not seem an appropriate assumption for a small open economy in long run equilibrium with mobile capital. The closure assumption adopted here at a minimum allows the economy's capital stock to adjust to changes in relative factor prices. The calibration method for long-run equilibrium analysis can clearly only be determined after some appropriate concept of *long-run* equilibrium is adopted. Implicit in the calibration adopted here is the assumption that ceteris paribus, net capital inflows or outflows are not expected to be large, relative to the aggregate stock of capital. Thus in the benchmark the current account deficit (surplus) is a genuine transfer from foreigners to Canadians (in aggregate) which is expected to be temporary. If the 'true' situation is one of long term capital inflows then this calibration procedure is inappropriate, and indeed the usefulness of the static equilibrium concept is questionable.

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[60] For example the current version of GET is calibrated to a 1981 benchmark. In 1981 the observed deficit on current account (BOP) is $ 5346.0 (millions of Cdn $).

5.11 Base versus the Benchmark

In the design of a calibration program it should have the property that given a set of exogenous parameters there should be one equilibrium which reproduces *exactly* the benchmark. This should be the case even if these are not the parameters used ultimately for counterfactual policy analysis. The usefulness of such a procedure lies in the ability to check calibration equations, coding and data. It is quite possible that errors can be introduced at anyone of these steps. Within the GET calibration program, TEST, an artificial equilibrium which mimics the benchmark can be produced by first calibrating the model using the following assumptions.

(A) Conjectural variations, cv_i's, must be set using rule (9.12) such that markups on observed unit costs reproduce producer prices equal to 1.0. The simulation equilibrium algorithm is then used to produce a quasi-equilibrium with

(1) the industrial structure parameters $\mathcal{I} = (\nu, \Delta)$ held constant at the benchmark values, and

(2) the exogenous transfer of income from foreigners, BOP, held constant at the benchmark value.

(3) the value of exogenous final sales, VXS, and the vector of sales XFS, held constant at benchmark values.

Under these hypotheses a quasi-equilibrium of GET should reproduce exactly the benchmark data set.

For purposes of counterfactual policy analysis, the benchmark is not necessarily the relevant reference point. The proposed alternative is a full long run equilibrium of the GET model using the parameter values calibrated as described in section 3-9, with the exogenous transfer component BOP set equal to 0 and VXS and XFS set equal to 0. This equilibrium is in some sense the most appropriate equilibrium from which a relevant counterfactual can be conducted. This equilibrium, referred to as the *base equilibrium* will differ from the benchmark because a number of equilibrium forces are allowed to work on the model which are conditions the data of the benchmark does not satisfy. Of particular importance are (a) the way in which capital stocks and rentals are measured in the benchmark, (b) the calibration of average cost in increasing returns industries, and (c) the calibration of pricing rules. Changes in any of these procedures, or *of any of the key elasticities which serve as input to the calibration procedure,* will result in potential differences between the benchmark and the base. Some parameters are more important than others such as the degree of scale economies assumed in each industry.

For purposes of keeping track of the performance of the calibration procedure it may be advisable to have a summary statistic which reports a measure of the difference between the base and benchmark. Letting the superscript b denote the base, and superscript o the benchmark, a natural measure is

$$D_1 = \Sigma_{i\in M}|X_i^b - X_i^o|/\left(\Sigma_{i\in M}X_i^o\right) \tag{11.1}$$

This measures the percentage deviation of absolute output changes, as a percent of total benchmark output. Another measure would focus on changes in industrial structure. Thus define

$$D_2 = \Sigma_{i\in N} |\nu_i^b - \nu_i^o|/ \left(\Sigma_{i\in N} \nu_i^o\right), \tag{11.2}$$

a measure of the change in the number of firms between base and bench, and

$$D_3 = \Sigma_{i\in N} |\Delta_i^b - \Delta_i^o|/ \left(\Sigma_{i\in N} \Delta_i^o\right) \tag{11.3}$$

a measure of the change in markups between the base and bench. The latter measure would reflect any dramatic changes in pricing structure induced by the transition from a benchmark to a base.[61] Finally a simple comparison of aggregate wages, and GDP between the two data sets would be useful.

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[61] Note that the Δ^o (11.3) are the markups after the correction for the appropriate cv's. The markups in the base will typically differ relative to the benchmark, because of the way in which the calibration of the cv's is undertaken, plus any general equilibrium effects.

Chapter 6

The G.E.T. Computational Algorithm

6.1 Introduction

This chapter deals with the computational issues in computing equilibrium of the GET model as described in chapters 2 and 4. In the early days of applied general equilibrium modelling, the details of fixed-point calculations occupied a good deal of researcher's attention; with the dramatic increase in lower cost computer power, the limits of large scale computational requirements have been reduced significantly. For non-linear models of the CGE variety conventional non-linear solution routines, using variants of Newton's method such as those available in the NAG subroutine library are fairly easy to adapt to most models. However even in 1988 for large non-linear, non-recursive models, meaning models with more than forty functionally dependent equations, computational costs can be significant. The larger CGE models, such as ORANI or VARUNA still use linear methods.[62] The current version of GET has 89 sectors, and thus might be viewed a medium size model. However because of the increasing returns to scale, entry/exit of firms, the model is highly non-linear. The computational algorithm used is thus not general, but specific to the GET model and uses the economic structure of the model heavily in facilitating equilibrium computations.

The fortran program (referred to as PILOT) which contains the solution algorithm, will compute either (i) a short-run equilibrium with the number of firms held fixed; i.e. fixed costs become sunk costs and the time period is sufficiently short to exclude entry; (ii) a long-run in which all economic profits are zero and all markets clear; and (iii) a Keynesian extreme short-run in which wage rates and exchange rates are fixed, commodity markets clear but labour markets don't and aggregate income equals aggregate expenditure (this version is referred to as PILOTK). Finally PILOT also computes a "benchmark equilibrium" for the purposes of checking the calibration done in the program and a base equilibrium as described in chapter 5 for reference purposes in doing counterfactual policy analysis.

The original PILOT program was written in the fall of 1982.[63] Since then it has undergone numerous tranformations. The basic structure is the same however and depicted in Flowchart 1. The program has a principal subroutine called LABOR, which essentially involves computing a conventional sort of equilibrium equating demand and supply using the input-output structure of the economy. Other variables relating to policy or the industrial organization features of the economy are manipulated in the main program.

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[62] See Dixon et. al.(1981) or Ginsburgh and Waelbrock (1981) for discussions of their solution method. Both use variants of the Johansen (1960) class of linearized models.

[63] The original program was written by R.G. Harris in the fall of 1981, and subsequently reworked by D. Cox and R.G. Harris in the period 1982-1984. In earlier documentation the fortran program was referred to as MATTHEW.

6.2 LABOR Subroutine

Most of the detail pertaining to functional forms of utility, production and cost, export demand equations, etc., is contained within LABOR. In principle changes in functional form should result in coding changes only within LABOR. Currently LABOR uses its own algorithm for generating "conditional" equilibrium prices, wages, income and industry outputs. While any standard algorithm for solving a system of non-linear equations would "work" given sufficient time and computer power, the particular procedure used within LABOR exploits the economic structure of GET to reduce the necessary computations. Given the large dimension of the model this is of considerable importance.

In Flowchart 2 the structure of the LABOR subroutine is outlined. The algorithm starts with a given wage w, and income level, I. Ad valorem distortions are held constant throughout the computation of a given equilibrium. The vector of prices is denoted by $\mathcal{P} = (w,r,P,P^*)$.

where w: supply wage rate

r: vector of rental rates on capital

P^*: vector of exogenous U.S. and R.O.W. prices

P: vector of endogenous Canadian producer prices

The unit cost function for the ith industry is $c_i(w,r,P^*,P)$,[64] and δ_i is the markup of price on unit cost. For a given δ, w, r, and P^* the first part of the subroutine involves solving the system of equations

$$(1) \qquad c_i(w,r,P^*,P) = \delta_i P_i \;, \; i \epsilon \mathcal{N} \qquad (2.1)$$

for the vector of domestic producer prices $P = (P_1, \ldots, P_n)$, with $n = 88$.

Solution methods for solving this set of equations (2.1) include in the Cobb-Douglas version of the model solution by matrix inversion. With a strict Cobb-Douglas cost function, including Cobb-Douglas sub-aggregators over materials, by taking the log of both sides of (2.1) and collecting terms one obtains a linear system of equations in the vector p= log P. Using a routine to solve systems of n-linear equations in n-unknowns is clearly the most efficient way to calculate the solution vector p. For more general cost functions a different solution method is required. One available method is to use a standard non-linear package based on Newton's method, or a variant of it.

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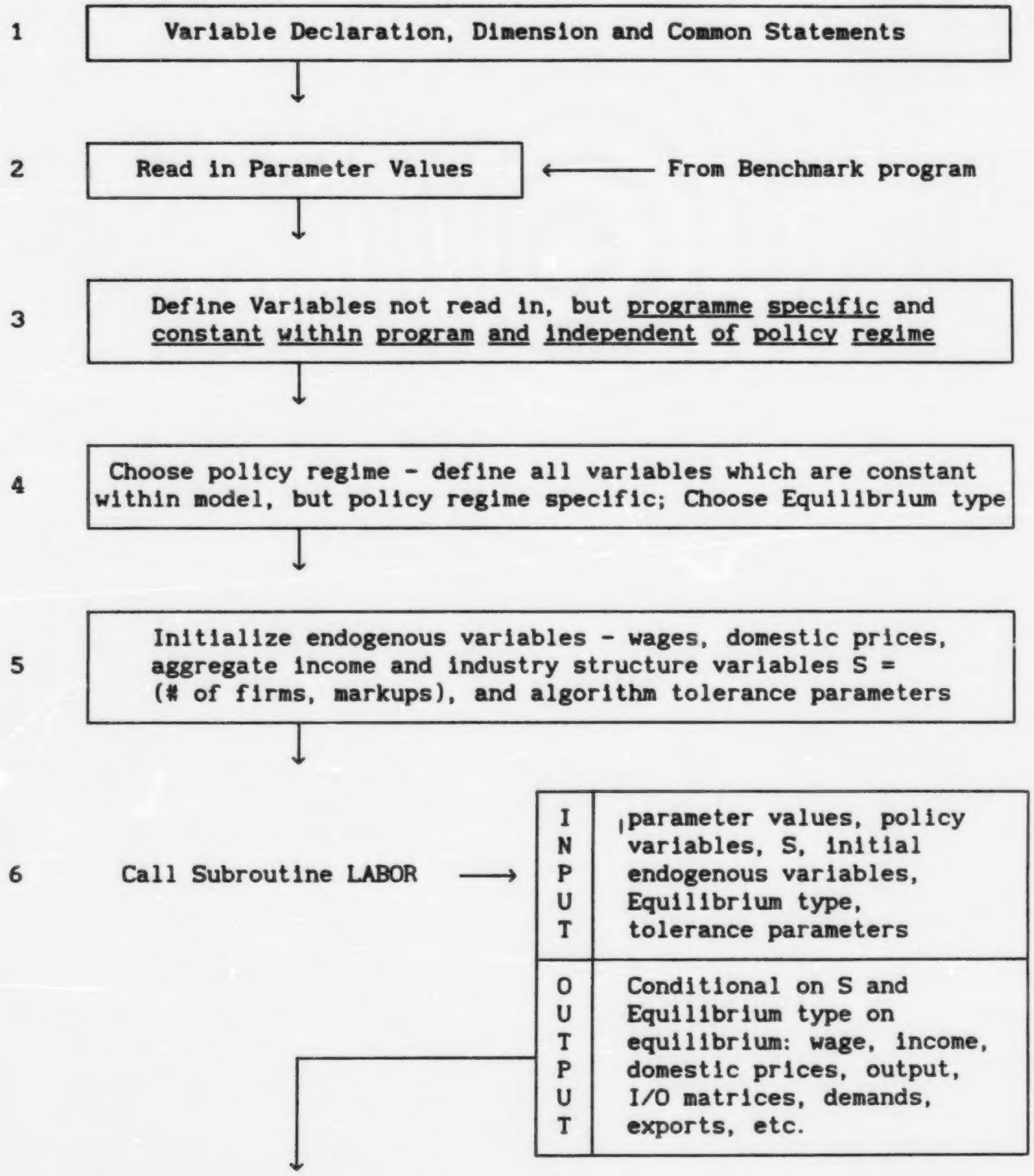
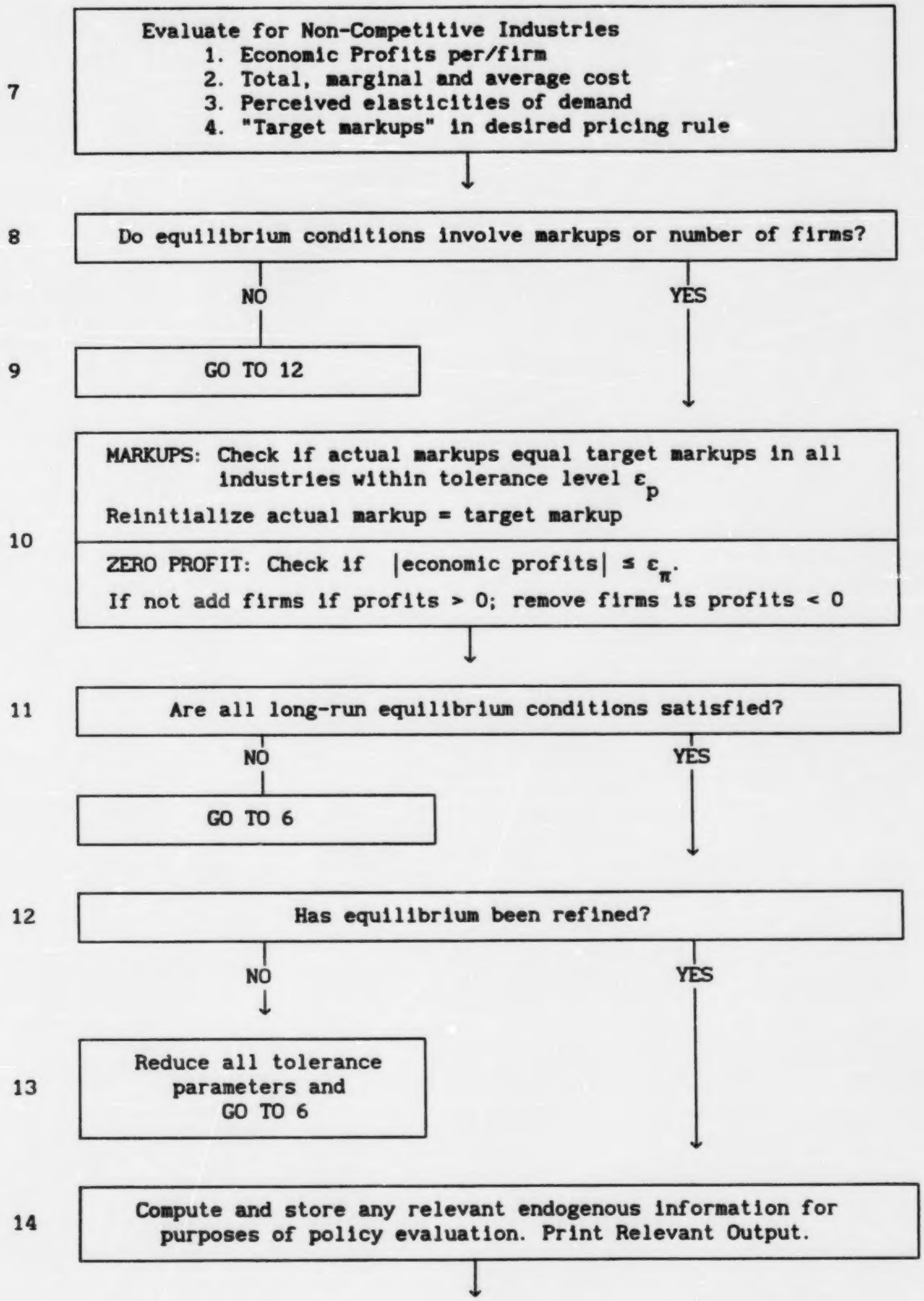
[64] To simplify notation we drop the detail regarding individual distortions as they affect the price=unit cost equation. This detail is contained in chapter 2. Since distortions are held fixed throughout a given equilibrium computation there are no signifcant features of the algorithm per se which depend upon an explicit introduction of all relevant model distortions.

PILOT Program Structure

Flowchart 1


1
Variable Declaration, Dimension and Common Statements
2
Read in Parameter Values
From Benchmark program
3
Define Variables not read in, but programme specific and constant within program and independent of policy regime
4
Choose policy regime - define all variables which are constant within model, but policy regime specific; Choose Equilibrium type
5
Initialize endogenous variables - wages, domestic prices, aggregate income and industry structure variables S = (# of firms, markups), and algorithm tolerance parameters
6
Call Subroutine LABOR
INPUT
parameter values, policy variables, S, initial endogenous variables, Equilibrium type, tolerance parameters
OUTPUT
Conditional on S and Equilibrium type on equilibrium: wage, income, domestic prices, output, I/O matrices, demands, exports, etc.



7 Evaluate for Non-Competitive Industries

1. Economic Profits per/firm
2. Total, marginal and average cost
3. Perceived elasticities of demand
4. "Target markups" in desired pricing rule

8 Do equilibrium conditions involve markups or number of firms?

NO

YES

9 GO TO 12

10 MARKUPS: Check if actual markups equal target markups in all industries within tolerance level ε_p

Reinitialize actual markup = target markup

ZERO PROFIT: Check if $|\text{economic profits}| \leq \varepsilon_\pi$.

If not add firms if profits > 0; remove firms is profits < 0

11 Are all long-run equilibrium conditions satisfied?

NO

YES

GO TO 6

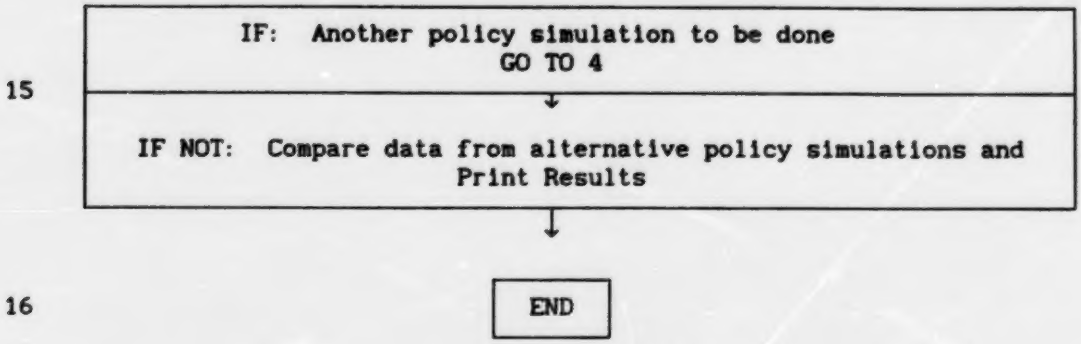
12 Has equilibrium been refined?

NO

YES

13 Reduce all tolerance parameters and GO TO 6

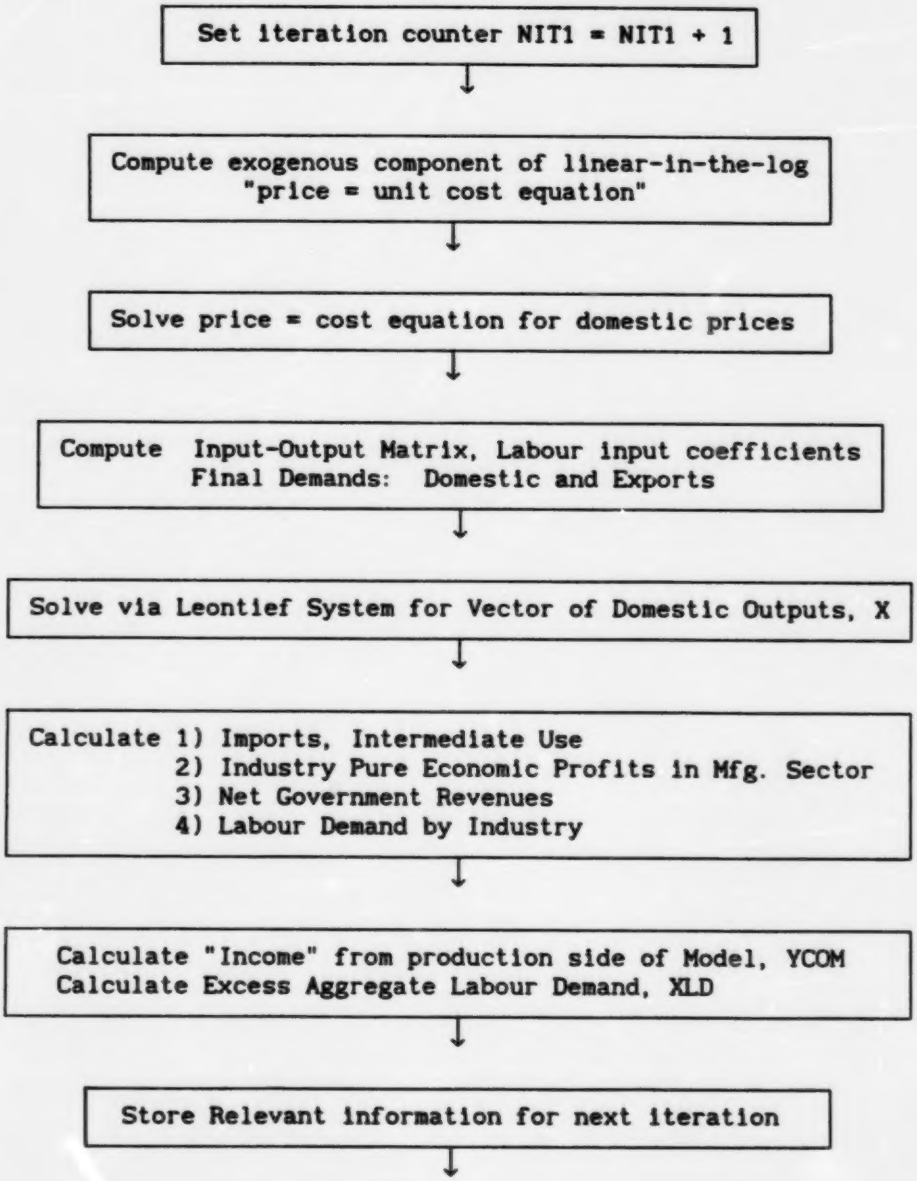
14 Compute and store any relevant endogenous information for purposes of policy evaluation. Print Relevant Output.

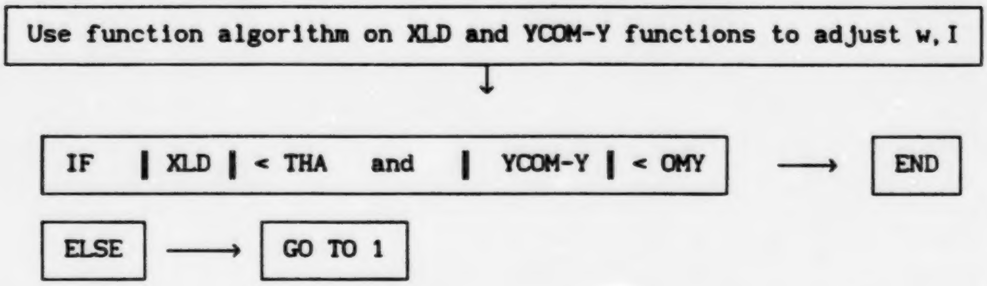

15
IF: Another policy simulation to be done
GO TO 4
IF NOT: Compare data from alternative policy simulations and Print Results
16
END

LABOUR SUBROUTINE
PROGRAM

Flowchart 2

Pass wage, w and "expenditure" Y from main program.


Set iteration counter NIT1 = NIT1 + 1
Compute exogenous component of linear-in-the-log "price = unit cost equation"
Solve price = cost equation for domestic prices
Compute Input-Output Matrix, Labour input coefficients
Final Demands: Domestic and Exports
Solve via Leontief System for Vector of Domestic Outputs, X
Calculate 1) Imports, Intermediate Use
2) Industry Pure Economic Profits in Mfg. Sector
3) Net Government Revenues
4) Labour Demand by Industry
Calculate "Income" from production side of Model, YCOM
Calculate Excess Aggregate Labour Demand, XLD
Store Relevant information for next iteration


Use function algorithm on XLD and YCOM-Y functions to adjust w, I
IF | XLD | < THA and | YCOM-Y | < OMY
END
ELSE
GO TO 1

A more efficient approach to solving for commodity prices is based on the *iterated cost function mapping* approach is used within GET and is recommended. This method exploits the particular properties of the unit cost functions $c_i(\bullet)$.

It is well known from economic theory, that the cost functions c_i satisfy the following properties:

A1. For strictly positive $\mathcal{P}$, c_i is positive.

A2. For all (w, r, P^*) strictly positive, c_i is a concave, non-decreasing function of P.

Let us also assume that a solution exists:

A.3 For strictly positive (w, r, P^*) and strictly positive δ there exists at least one strictly positive solution P^S to (2.1).

It is possible to show that given these assumptions P^S is unique, and furthermore it is the limit of the *iterated cost function mapping* defined by

$$P^{t+1} = \delta\, c(w, r, P^t, P^*) \tag{2.2}$$

(2.2) maps prices in R^n_+ to a vector in R^n_+. The limit reached computationally by iterating on (2.2), equals P^S. In practice iteration stops when

$$|P^{t+1} - P^t| < \varepsilon, \tag{2.3}$$

for some tolerance parameter ε.[65] The proof that this converges to a unique solution depends upon showing that the mapping (2.2) has a unique solution.[66]

Once prices are determined the next step in the algorithm is to calculate the input-output coefficients matrix A, labour requirements coefficients a_w, and the vector of final demands, F. Once this is done a vector of total domestic industry outputs X, is calculated by the Leontief calculation

$$F + AX = X \tag{2.4}$$

(2.4) is solved using a routine on n simultaneous linear equations in n unknowns.

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[65] Note that in choosing the tolerance parameter ε in (2.2) it should be scaled to the size of the vectors P; thus if P is of dimension n, ε should be linear in n. Within GET since all producer prices are scaled to unity in the benchmark the norm of P is in the order of n. Thus set $\varepsilon = .0001 \times n$ for example.

[66] A proof of uniqueness is straightforward following Arrow and Hahn (1971) chapter 9 for $\delta = \underline{1}$. For δ too large A.3 will be violated.

Given prices, output, and wages, government revenues and industry profits can be calculated, which can then be used to construct an estimate of consumer income I', inclusive of government transfers. At the same time, labour demand is calculated using X and a_w. A new wage w' is generated using a simple excess demand rule with the wage rate rising (falling) if excess labour demand is positive (negative). The whole process repeats with a new wage and income. This continues until the labour market clears and income stabilizes. In practice this subroutine computes equilibrium in labour and commodity markets extremely fast. Occasionally failure of convergence arises if starting values for w and I are a long way from the equilibrium values. However failure to converge usually indicates something is wrong, either in the code or in the data and parameter values passed to LABOR.

The general structure of the numerical algorithm in LABOUR can thus be summarized as follows. The algorithm operates on a pair of variables (w, I). Given a particular pair of values for these variables two function evalutions are carried out.

(1) a function describing aggregate labour demand minus labour supply is constructed by using the price = cost condition, and the Leontief relationship for industry total outputs. This function is denoted by

$$F_1(w, I) = L^D(w, y) - \bar{L} \qquad (2.5)$$

(2) Another function determines the income of the aggregate consumer, given the labour supply, $\bar{L}$, the wage w, and other income sources from aggregate profits and government transfers consistent with the prices and outputs determined by the price = cost condition and the vector of outputs consistent with equilibrium in the product markets. Call this function the *target income function*, $I^*(w, I)$. The second function is then

$$F_2(w, I) = I^*(w, I) - I \qquad (2.6)$$

A solution vector (w°, I°) satisfies

$$F_1(w^\circ, I^\circ) = 0$$

$$F_2(w^\circ, I^\circ) = 0.$$

Thus the labour market clears and target income equals actual income. The actual algorithm used to get a solution vector is quite rudimentary involving an iterative procedure on w and I. The rules used in the current version of PILOT for iteration on w and I are:

Rule 1. If $\bar{L} > L^D$ $\quad w_{t+1} = 0.5(w_t - D) + 0.5\, w_t$

Rule 2. If $\bar{L} < L^D$ $\quad w_{t+1} = 0.5(w_t + D) + 0.5\, w_t$

Rule 3. The wage adjustment increment in iteration t, D_t, is is chosen so that

(a) Its scale is a step function of the size of $|L^D - L|$.

(b) The sign of D equals the sign of $-D_{t-1}(L^D_t - L^D_{t-1})$

Rule 4. The income adjustment rule is

$$I_{t+1} = 0.5\, I_{t-2} + 0.5\, I_{t-1} + 0.5\lambda[B_t - I^*(w_t, I_t)]$$

$$\text{with } B_t = 0.5\,[\lambda I^*(w_t, I_t) + (1-\lambda)I_t] + 0.5\, I_{t-2}.$$

λ is a parameter between 0 and 1; in practice $\lambda = 1/2$ works well. The algorithm converges when both F_1 and F_2 take on absolute values less than ε_L and ε_I respectively. In practice these tolerance parameters are chosen to equal $\varepsilon_L = .0001x\bar{L}$ and $\varepsilon_I = .0001xI^b$ where I^b is base income. Thus computed values are within approximately one tenth of one percent of the true equilibrium value.

Any numerical algorithm not requiring analytical derivatives could be used to solve for the zero's of F_1 and F_2. The one decribed seems to work quite efficiently, but in future versions of GET a more sophisticated numerical algorithm might be appropriate.

6.3 MAIN Program: Industrial Structure and Equilibrium Refinement

Once LABOUR has calculated all equilibrium income, product and prices for a given industrial structure control passes back to the main program in PILOT. At this point two things are checked. 1) Economic profits are calculated in all non-competitive industries, and 2) actual markups are checked against target theoretical markups. If economic profits are postive in an industry, $i \in A$, the algorithm adds additional representative firms to the industry; if profits are negative the algorithm removes firms from the industry. At the same time markups are set in accordance with the pricing rules being used in the model.

The actual iteration rule used on the number of firms is quite simple, but to avoid cycling problems some appropirate scaling procedure is desireable. Let the subscript τ index the iterations in the MAIN part of PILOT, ie. iterations on industrial structure parameters. The rule for adjusting the number of firms is then

$$\nu_{j,\tau+1} = \nu_{j,\tau} + \gamma\, \rho_j \nu_{j,\tau} \tag{3.1}$$

where the parameter ρ_j provides a scaling of the degree of excess pure profit in industry j. Specifically

$$\rho_j = \Pi_j / P^c_j X_j \tag{3.2}$$

Note this measure scales pure profit relative to sales in industry j. To speed up the algorithm the speed of adjustment parameter γ is scaled to the magnitude of $|\nu_j|$. In addition to avoid cycling problems around the solution value, when profits switch back and forth from positive to negative between consecutive iterations the following conditional rule is adopted on changing the number of firms:

If $\rho_{j,t} \times \rho_{j,t-1} < 0$ then (3.1) is replaced by

$$\nu_{j,t+1} = 0.5\ \nu_{j,t-1} + 0.5\ \nu_{j,t} \tag{3.1'}$$

In the course of the algorithnm searching for an equilibrium number of firms certain boundary problems may be encountered as ν_j approaches one. This will be discussed in section 4 below.

Once markups and the number of firms have been set the control passes back to LABOUR. The program iterates this way until all economic profits are approximately zero, and actual markups are approximately equal to target markups. Upon satisfying these approximate equilibrium conditions a procedure known as 'refinement' of the equilibrium occurs. All tolerance parameters are reduced to 0.10 of their initial values and the whole exercise is carried out again. The final equilibrium is typically subject to a 0.01% accuracy. That is excess labour demand, profits, and target markups are within one hundredth of one percent of exact equilibrium values.

When the final refined equilibrium is computed the PILOT program carries out a large number of calculations on the equilibrium data computing relevant index numbers summarizing the characteristics of the equilibrium as discussed in chapter 3. It will also go on to compute other equilibrium under different assumptions as to policy variables, and construct the relevant summary statistics comparing one equilibrium with another. This part of the program can be changed quite easily by users depending upon what they wish to do with the model. However considerable care should be exercised in making changes within the core part of the program that computes equilibrium. Errors here are more difficult to check and furthermore any undetected errors can render the results useless.

It is worth pointing out that the existing structure of the PILOT program draws much of its simplicity from the separation of adjustment in industrial structure variables from the computation of equilibrium prices and flows. This separation will not be valid if marginal costs within the non-competitive industries are non-constant. Work by McDonough (1987) has shown it is possible to solve a more general model but at considerable computational cost. For a large model such as G.E.T. it would be necessary to use a very large computer (a CRAY for example) to carry out calculations using general assumptions on the cost functions. This extension however is quite feasible and probably not too far off in terms of practical computing cost considerations.

6.4 Boundary Problems and Solution Concepts

Two practical boundary problems arise in solving this particular version of GET. The first problem is what happens when the number of firms is driven towards zero in industries that are persistently operating at a loss within the model's parameter range. Conventional theory would suggest that these industries should be shut down. On the other hand the strict Armington assumption will usually guarantee that for almost all parameter values there will exist some price sufficiently high at which some positive output is demanded and covers costs.[67]

The second problem, comes from bounding output of indiviudal firms above by some level, y^B. The logic behind doing this is the notion that the true cost curve is actually U or L-shaped, giving a reasonable upper bound to true cost savings achieveable through increases in individual firm scale. While bounding outputs is a reasonable assumption it does create certain problems in the design of the solution algorithm. We shall treat each of these problems in turn.

Within the solution algorithm y^B is defined as $1.05y_m$. This fairly arbitrary definition seems quite sensible given the cost function approximates cost savings over the interval $[\bar{y}\ ,y_m]$ reasonably accurately. In the solution algorithm, just after target markups are set, but before the number of firms is set, there is a conditional statment which says:

$$\textit{If } y > y^B \textit{ then } \delta_i \textit{ must be set such that } P_i^c(1+\theta_i^o) = AC_i. \qquad (4.1)$$

The impact of this statement is that in the next loop in the MAIN program price will equal average cost. Thus profits will equal zero, and there will be no change in the number of firms within this industry. Provided the solution algorithm approaches y^B from below, upon reaching the upper bound on output, the algorithm will keep the number of firms constant. Of course, output per firm is demand determined, and once the number of firms is set output per firm can change because of general equilibrium price and income effects. Thus it is quite possible that the equilibrium will have the characteristic that $y_i > y_i^B$ in some industries. Once the algorithm enters a region of the industrial structure space, such that at a given $\mathcal{S}$, for some of the industries $y > y_i^B$, the conditional statement in this case forces the price equal average cost solution on all such industries. It is conceivable that the new price after imposition of (4.1) will be *lower* than the theoretically correct price. In this case demand increases and output per firm continues to exceed y^B. With profits now zero in that industry no entry or exit will occur, and the algorithm will converge with $y > y^B$. It is quite likely this outcome is inconsistent with the basic pricing theory and cost structure of the A industries. It should be noted however that if free entry were dropped as a requirement of equilibrium in the A group, then this ad hoc imposition of price equal to average cost would be quite inappropriate, and other methods of dealing with the cost function aproximation issue would be required. It is advisable to check the markups on all industries which have outputs at or above the boundary value. If these markups differ considerably from the theoretically appropriate markups it may be advisable to raise the upper bound for that industry and resolve the model.

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[67] Even this is not strictly true however given CES Armington aggregators. With the CES functional form, and an Armington elasticity of substitution $\sigma > 1$, the indifference curves between foreign and domestic goods actually cut the axis defining the positive orthant, the relevant choice space for the consumer. Thus at some finite relative price of domestic to foreign goods which is sufficiently high, the consumer will in fact choose to consume a zero quantity of the domestic good. In practice however this never seems to occur.

The problem of dealing with the shutting down of industries poses a difficult issue, of not only for solution algorithms, but the interpretation of that event should it occur in a particular simulation. An ad hoc approach to checking for industries which might shut down in equilbirum would the following procedure.

(i) Check a for a failure of convergence to a zero profit equilibirum by verifying which industries were running persistent losses with the number of firms, ν_i bounded above 1.0.

(ii) Shut the industry down in an artificial sense by computing the shadow price at which demand for industry output is zero. Call this price P_i^{max} if industry i shuts down. This price is in general a function of all other prices of produced goods.

(iii) Solve the model removing the ith good entirely, and hence the ith industry.

(iv) Check if the solution satisfies the restriction that at the P_i^{max} consistent with this equilibrium, hypothetical average cost of production at any level of output, would be such that given a conjectured demand curve a single firm could not make money at any level of output.

If condition (iv) holds then the equilibrium without good i being produced seems plausible. It is sort of analogous to the condition in constant returns models, that in equilbrium without good i, it must be the case that price is less than average cost in that industry. If not, then entry could be expected to occur, and good i must be re-introduced into the set of products being produced.

By searching iteratively this manner in an exhaustive way it would be possible to locate those products which would likely be eliminated say due to intense foreign competition. Computationally this procedure is extremely cumbersome, and for large models is practically not feasible. A more efficient, albeit ad hoc approach, is required. Within the GET algorithm the principal working assumption is:

If the number of firms which can survive in equilibrium using the relevant pricing theory is two or less, the pricing conduct of the industry transforms structurally, to average cost pricing taking whatever demand can be sold at those prices.

The situation is illustrated in figure 6.1. At the target price P^T consistent with the appropriate pricing theory, demand is insufficient with one firm to cover average costs. By setting price equal to average cost at either P^H or P^L the firm could survive (ie cover costs). The assumption effectively adopted is that the low price equilibrium would occur, consistent with the basic tenents of contestability theory. However if there are exactly two firms, it is assumed that price is set by the relevant pricing theory. To smooth the equilibrium a non-integer number of firms between 1 and 2 is allowed with the selling price at a weighted average between the average cost price, and the target price. The weights reflect the fractional number of firms lying between one and two. Specifically the rule for A industries is:

If $\nu_i < 2.0$ then the markup δ_i is set by *the rule*

$$\delta_i = (\nu_i - 1)\delta_i^* + (2 - \nu_i)\frac{AC_i}{v_i\left(1 + \theta_i^o\right)} \qquad (4.2)$$

Since ν_i is bound from below from one, this rule sets the markups such that a smooth transition to average cost pricing is achieved as the number of firms approaches 1.0. Even using this rule there is in principle the possibility that there is no price at which even a single firm can break even. In figure 6.1 this would be the case if the demand curve lay entirely below the average cost curve. In practice this does not however seem to occur. Note that rule (4.2) has the convenient property that the markup is continuous in the number of firms. This eliminates any cycling problems a discontinuous rule might cause.

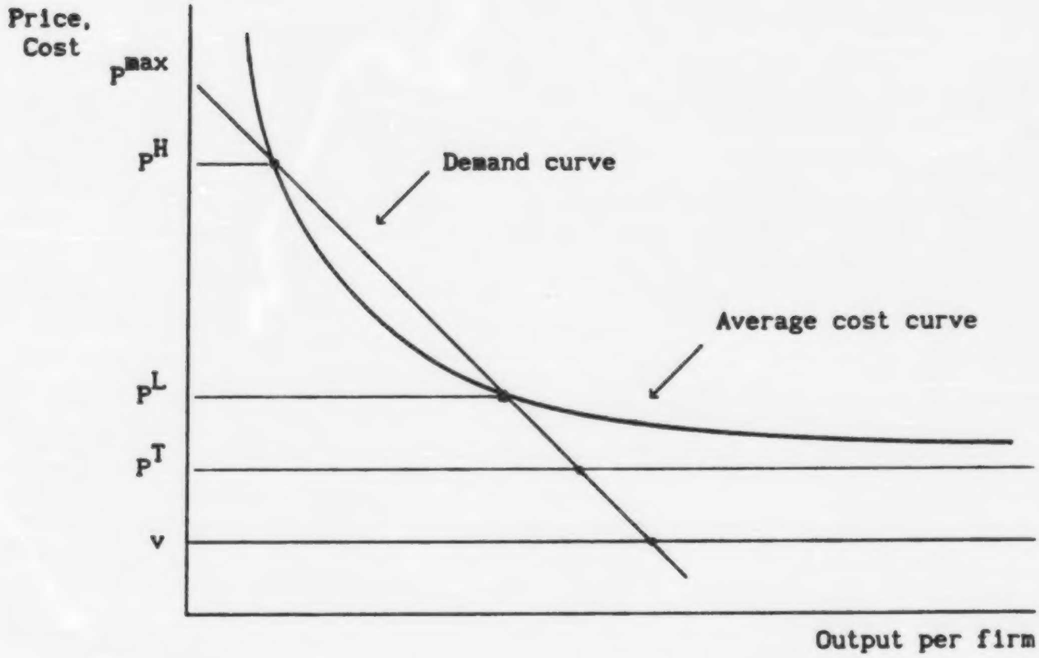
6.5 Coding Changes in Model Structure

Users of the GET model will inevitability be interested in the introduction of changes to model structure. This chapter is concluded with some pointers as to how errors can be minimized, and in constructing the appropriate changes in the solution algorithm when necessary.

First, any changes in model structure, no matter how simple, may have important consistency implications elsewhere in the model. Often writing down a very simple 2 or 3 sector version of the model, with a minimal number of factors and goods will help considerably in making sure the accounting framework and adding up conditions have been modified appropriately. Once these have been checked the next step is to investigate any changes to the solution algorithm necessary.

Figure 6.1

Pricing in A Industries as Number of Firm Tends to One



Second, write down all the necessary equilibrium conditions, and count the number of equations and unknowns. Adding up conditions will usually eliminate one equation and one unknown.

Next, make sure that each equilibrium condition is met in the solution algorithm. If variables are being solved for iteratively by a search procedure, make sure the rule used is continuous in the underlying variables, and avoids cycling by moving the variables in the wrong direction.

The most important check however is in the benchmarking procedure. If at all possible the calibration program should be changed in such a manner that a data set can be reproduced as an equilibrium of the appropriate model. This process should eliminate most errors. It is in fact possible to write a program that compares the data set of the calibration program, and the output of the equilibrium program and identifies exactly where they differ. While writing such a program can be time consuming it is often well worth the effort as a means of debugging a large scale model.

An additional programming aid to larger models, and one not used in the current versions of PILOT and TEST is the use of function calls in the use of basic functional forms. If for example an particular funtional form is being used for export demand, or average cost, writing one function subroutine and then calling it as necessary throughtout the equilibrium and calibration programs is superior to re-writing the function code over repeatedly. Any errors must then only be discovered once. In addition if a change in functional form is desireable, it requires only re-writing a small part of the code.

Finally a warning regarding boundary values. One is often forced to resort to setting an ad hoc boundary value for a particular variable, perhaps because one industry, or variable is behaving peculiarly in a particular set of simulations. Imposing a conditional boundary value statement can be helpful and even have valid economic intrepretations in certain circumstances, but *the modeller should always be aware of how many variables are being set by the conditional boundary value statement*. This statement should be reported as a routine part of simulation output. Failure to do so will lead to the following sequence of events. The model is changed for some purpose, and in the course of doing so a particular boundary value is imposed on some variable. After some period of time, or alternatively use of the same model by a different person(s), the model is changed back to its apparently original form. However in doing so the boundary conditions are not removed. Results from the apparently old model appear to be quite different than they were previously. The reason is, of course, the boundary conditions being imposed on some variables. There is no question that in large programs it is extremely easy to make this type of mistake. The problem is compounded further in circumstances when more than one individual is working on the same set of model code.

Appendix 1

Benchmark Data Construction

(prepared by David Cox)

A1.0 Introduction

In this appendix the construction of the benchmark data used to calibrate the Finance-GET model is outlined. The basic data source for the benchmark data set is the set of input-output (I-O) tables obtained from Statistics Canada for the year 1981. Much of this appendix deals with the modifications of this basic data source to get it into a form consistent with the underlying general equilibrium model. Many aspects of the procedures used in this reconciliation are discussed in St. Hilaire and Whalley (1983). The actual manipulations of the data are carried out in the FORTRAN program FUNK. This appendix describes these data manipulations roughly in the order that they executed in the FORTRAN program. In addition, the sources of some data other than the I-O data used to calibrate the model are presented in this appendix.

A1.1 Input-Output Data Obtained from Statistics Canada

The I-O tables used to calibrate the model were obtained from Statistics Canada. The tables refer to the year 1981. The year 1981 was selected as this was the latest year that the tables were available when the project began.

The I-O data obtained from Statistics Canada was based on a 92 industry aggregation level and consisted of two matrices: an inter-industry flow matrix describing the use of intermediate inputs and primary inputs by each industry and a final demand matrix which describes the use of net industry output and primary inputs by each of 136 final demand categories. These tables were constructed by aggregating industries from the L-level aggregation of Statistics Canada, consisting of 191 industries, to the 92 industry aggregation. The tables that we obtained from Statistics Canada differ from the published versions of the I-O tables in that they are based on a "square framework", tracing the flow of aggregate industry output, rather than the "rectangular framework" which traces the flow of commodities produced by each industry. The rectangular framework distinguishes the inputs and outputs of industries on a commodity basis with the number of commodities exceeding the number of industries. This accounting framework requires the use of three matrices – a Make Matrix showing the production of commodities by each industry, a Use Matrix showing the input use of commodities and primary inputs by each industry, and a Final Demand Matrix showing the use of commodities and primary inputs by each Final Demand category – to describe the economy's I-O flows. In order to aggregate the three rectangular matrices into two square matrices, consistent with the framework of the Finance-GET model, the following procedure was followed by Statistics Canada. First, a market share matrix was constructed, based in the Make Matrix, which shows the share of the output of each industry which was produced by each industry. Second, on the assumption that the share of commodity output produced by each industry is fixed regardless of the level of commodity production, the Use Matrix and the Final Demand matrices were pre-multiplied by the market share matrix. The result is two matrices – a Use and Final Demand matrix – organized on an industry basis rather than on a commodity basis. It is on the basis of these matrices that the calibration of the Finance-GET model was undertaken. For more details of the procedure used to move from a rectangular accounting framework to a square framework the reader is referred to Statistics Canada (1986).

A1.2 Aggregation of Industries and Commodities

(i) Treatment of the Dummy Industries

In addition to the Standard Industrial Classification (S.I.C). industries the I-O accounts include three "dummy" industries. In the CHM aggregation they are the following industries: Office, Laboratory and Food Operating margins, Travel and Advertising margins, and Transportation margins. The dummy industry is an accounting technique used to assign groups of commodities, such as office supplies, as inputs into industries where it is difficult to determine the exact commodity content. The output of a dummy industry is produced solely with intermediate inputs; there is no value-added associated with a dummy industry. Since the dummy industries have no theoretical counterpart in the Finance model it was decided to remove them from the I-O tables. The procedure used to delete these industries was to allocate their commodity inputs directly to the S.I.C. industries and categories of final demand in proportion to their demand for the output of the dummy industries. In the modified I-O tables which result from this procedure all of the relevant accounting identities are maintained.

(ii) Commodities

In some cases the commodity disaggregation present in the I-O tables is too detailed for our purposes. As a result a number of commodities were combined to form more reasonable aggregates. For example, the commodity Government goods and services (commodity 102) was added to Personal and Miscellaneous services, in both intermediate and final demand uses to form the commodity Miscellaneous services. In addition commodities 93 through 101, various types of non-competing imports, were aggregated together to form one commodity "Non-competing imports".

A1.3 Treatment of Government Royalty Payments

In the I-O tables obtained from Statistics Canada government royalties paid by industries are treated as a margin. Government royalties are considered, therefore, as a separate industry. The payment of government royalties by industries is considered the output of the "government royalties" industry. The only input payment recorded in this industry is "other operating surplus" with a value equal to total government royalties paid by all industries.

In the Finance model government royalties are considered part of the value-added of the industry which pays them. To be consistent with this treatment government royalties paid by each industry were moved in the I-O tables to the category "other operating surplus. Consequently, to maintain the accounting balance of the I-O tables the industry Government Royalties and its value-added was deleted from the tables.

It is assumed in the Finance model that royalties are paid by industries as an ad valorem tax on gross value-added. Letting GVA_1 represent gross value-added (inclusive of government royalties) and ROY_i represent royalty payments, the ad valorem royalty rate RY_i was computed for each industry as:

$$RY_i = \frac{ROY_i}{GVA_i}$$

A1.4 Labour Income and Surplus

In the I-O tables four categories of payments to primary factors are distinguished - Wages and Salaries, Supplementary labour income, Net income of unincorporated business, and Other operating surplus. In the accounting used in the Finance model only two categories of income are needed - labour income and surplus (which in turn is allocated between capital income and profit income) - so aggregation of the four categories is required. To form an aggregate measure of labour income it was decided to add together Wages and Salaries and Supplementary labour income. In addition, this measure of labour income was augmented by a portion of the net income to unincorporated business which was deemed to accrue to labour. The remaining share of unincorporated business income was added to Other operating income to form the category Surplus. The shares of unincorporated business income accruing to labour and surplus were taken to be the same as the observed shares of surplus and labour in incorporated business income as obtained from the I-O tables.

A1.5 Re-arrangement of the Order of Industries

In the I-O tables obtained from Statistics Canada the ordering of the industries begins with the resource sectors (industries one through six), followed by the manufacturing industries (industries seven through sixty-nine) and the remaining service industries. In the PILOT program it is convenient to have the manufacturing industries positioned at the beginning of the list of industries so a re-ordering of the industries in the Use and Final Demand matrices was undertaken. The manufacturing industries are positioned as industries one through sixty-three, the resource industries are positioned next as industries sixty-four through sixty-nine, and the service industries occupy positions seventy through eighty-eight.

A1.6 Aggregation of Final Demand Categories

In the Canadian I-O tables 136 final demand categories are recognized. A listing of these categories accompanies the I-O data obtained from Statistics Canada. In the interest of model tractability these categories were aggregated into a smaller number of sectors. These sectors include consumption expenditure, investment expenditure, government expenditure, exports, and imports. Aggregate consumption is identified by the FORTRAN name CON in the FUNK program and is defined to include final demand categories 1 through 40 and category 117, aggregate investment, INV, includes categories 41 through 121 (excluding category 117), and aggregate government expenditure, GOV, includes categories 122 through 136 (excluding categories 128, 129, and 130). Exports are given by category 128. Imports are given by the difference between categories 130 and 129, that is imports are defined to be net of re-exports.

In the current version of the model consumption, investment and government expenditure are all further aggregated to form a single domestic final demand category. This aggregation procedure is discussed further in section A1.8 below.

A1.7 Exogenous Supply

Among the 136 categories of final demand are the categories of government supply categories 133-136 and withdrawals from inventories categories 78 and 120-122 which involve the supply of commodities rather than demand. The supply of a commodity in a final demand category is recorded in the I-O tables with a negative number. For some commodities, it is the case that when all categories of final demand (excluding exports and imports) are added together the result is a negative number (a net supply for that particular commodity). Unfortunately, this is not consistent with the behavior of the aggregate consumer postulated in the Finance model. There the behavior of the consumer is assumed to involve only the demand for commodities, not their supply.

In order to overcome this problem the following approach is adopted. If for a particular commodity i total investment INV_i or GOV_i is negative (ie. a net supply of good i) then INV_i or GOV_i is set equal to zero. The variable $EXFS_i$ (exogenous final supply) is then set equal to $-INV_i$ or $-GOV_i$ or the sum of both if both happen to be negative for the same good. The interpretation of this variable is that it involves a source of supply which is not generated by the current activity of the private production sector. This treatment of the final demand sector guarantees that final demand, for each commodity, will be a non-negative number and thus consistent with the behavior of the aggregate consumer. However in order to maintain the balance of supply and demand exogenous final supply must be added to domestic production for each commodity.

A1.8 Treatment of Imports and Exports

(i) Imports

In the Finance model a commodity is distinguished not only by its physical characteristics but also by the region in which it is produced - domestically, in the U.S.A., or in the Rest of World (ROW). This is the so-called Armington assumption. An I-O accounting framework consistent with this assumption requires the existence of three Use matrices showing commodity use by industry for domestic, American and ROW sources of supply. A similar division of final demand into its domestic, American and ROW components, is also required. Unfortunately in the published I-O tables information on commodity use by region is not directly provided. Each commodity entry in the Use and Final Demand matrices represents the sum of domestic, American and ROW commodity use. Information is provided only on the total imports (from all foreign regions) by all sectors, for each physical commodity type.

In order to split each commodity entry in the Use and Final Demand matrices into its domestic, American and ROW components the following procedure was followed. First, information was acquired on the regional composition of total imports for each commodity. This allowed us to split total imports for each commodity into an American and ROW component. Second, for each commodity, the ratio, μ_i^{US}, of imports from the U.S.A. to total commodity use was computed. Total commodity use is the sum of commodity use in all intermediate and final demand categories. A similar ratio, μ_i^{ROW}, was computed for ROW imports. Finally, the assumption was made that, for each physical commodity, the ratio of imports (American and ROW) to commodity use by each sector was the same as the ratio of total imports (American and ROW) to total commodity use. This assumption, which is common in input-output analysis, then allows us to split the Use and Final Demand matrices into their domestic, American and ROW components in the following manner.

Letting INPUT represent the (square) sub-matrix of the Use Matrix which contains the total flows of intermediate commodities, the domestic use matrix (DINPUT), American use matrix (USPUT), and ROW use matrix (RWPUT) matrices are defined as follows

$$\mathrm{USPUT}_i = \mu_i^{US} \cdot \mathrm{INPUT}_i$$

$$\mathrm{RWPUT}_i = \mu_i^{ROW} \cdot \mathrm{INPUT}_i \qquad i \in \mathcal{M}$$

$$\mathrm{DINPUT}_i = \left(1 - \mu_i^{US} - \mu_i^{ROW}\right) \cdot \mathrm{INPUT}_i$$

where INPUT_i represents the i^{th} row of the matrix INPUT and similarly USPUT_i, RWPUT_i and DINPUT_i represent the i^{th} row of the respective matrices.

Letting CON, INV and GOV represent the vectors of the final demand categories – consumption, investment and government – the domestic, American and ROW components are defined as follows:

$$\mathrm{USCON}_i = \mu_i^{us} \cdot \mathrm{CON}_i$$

$$\mathrm{RWCON}_i = \mu_i^{ROW} \cdot \mathrm{CON}_i$$

$$\mathrm{DCON}_i = \left(1 - \mu_i^{US} - \mu_i^{ROW}\right) \cdot \mathrm{CON}_i$$

$$\mathrm{USINV}_i = \mu_i^{US} \cdot \mathrm{INV}_i \qquad i \in \mathcal{M}$$

$$\mathrm{RWINV}_i = \mu_i^{ROW} \cdot \mathrm{INV}_i$$

$$\mathrm{DINV}_i = \left(1 - \mu_i^{US} - \mu_i^{ROW}\right) \cdot \mathrm{INV}_i$$

$$USGOV_i = \mu_i^{US} \cdot GOV_i$$

$$RWGOV_i = \mu_i^{ROW} \cdot GOV_i$$

$$DGOV_i = \left(1 - \mu_i^{US} - \mu_i^{ROW}\right) \cdot GOV_i$$

where the subscript i refers to the i^{th} element in each vector.

In the current version of the Finance model the consumption, investment and government components of final demand are aggregated into one overall category of final demand. The domestic (FDD), American (FDUS) and ROW (FDRW) components of final demand are defined as:

$$FDD_i = DCON_i + DINV_i + DGOV_i$$

$$FDUS_i = USCON_i + USINV_i + USGOV_i$$

$$FDRW_i = RWCON_i + RWINV_i + RWGOV_i$$

where the subscript i refers to the i^{th} element in each vector.

(ii) Exports

In the published I-O tables there is no information provided on the country to which domestic exports are destined. Information was obtained from other sources which allowed us to split, for each commodity, exports into their U.S.A. and ROW components. In the program FUNK these exports are identified by the FORTRAN names USEXP and RWEXP for U.S.A. and ROW exports respectively.

A1.9 Taxes and Subsidies

The commodity flows in the I-O tables are valued at estimated producers' prices rather than the actual transaction prices used in market exchanges. Conceptually a producers' price represents the price of an industry's output at the "factory gate". The difference between the actual transaction price and a producer's price includes other costs which are referred to in the I-O tables as margins. Among the various margins distinguished in the I-O tables are transportation margins, retail and wholesale margins, and tax margins. In the Use and Final Demand matrices the entries for the margin inputs refer to the total of each type of margin purchased by each sector. In this way the balance between the value of gross output and the value of payments to all inputs is maintained.

In the case of taxes, the conceptual framework of the Finance model is different from that of the I-O tables. In the model, the price paid by a purchaser of a commodity is assumed to be inclusive of any commodity taxes paid. For this reason the tax margins, where possible, must be allocated to specific transactions and tax rates computed. To this end information from Statistics Canada was obtained which allowed us to allocate, for each sector, the tax margin, Commodity Indirect Taxes, to actual commodity transactions. For the Use Matrix, three matrices of observed tax payments were obtained – a matrix of payments for federal sales taxes (Fortran name FST), a matrix of other federal taxes paid (Fortran name OFT) and a matrix of other indirect taxes paid (Fortran name OIT). Similar information for the vector of final demand transactions is contained in the vectors: FDFST (Final Demand Sales Tax), FDOFT (Final Demand Other Federal Tax) and FDOIT (Final Demand Other Indirect Tax). The following identities hold, for each sector, between the entry in the tax margin Commodity Indirect taxes and the taxes paid on an individual commodity basis:

Use Matrix

$$\begin{array}{c}\text{Commodity Indirect Taxes}\\ \text{for industry } j\end{array} = \sum_{i \in \mathcal{M}} \left(FST_{ij} + OFT_{ij} + OIT_{ij} \right)$$

Final Demand Vector

$$\text{Commodity Indirect Taxes} = \sum_{i \in \mathcal{M}} \left(FDFST_i + FDFT_i + FDOIT_i \right)$$

Using this information, transaction specific tax rates were computed for both intermediate and final demand uses. Intermediate tax rates for Federal Sales Tax, Other Federal Tax and Other Indirect Tax were computed as follows:

$$FSTR_{ij} = FST_{ij} \,/\, \left(Dinput_{ij} + Usput_{ij} + Rwput_{ij} \right)$$

$$OFTR_{ij} = OFT_{ij} \,/\, \left(Dinput_{ij} + Usput_{ij} + Rwput_{ij} \right)$$

$$OITR_{ij} = OIT_{ij} \,/\, \left(Dinput_{ij} + Usput_{ij} + Rwput_{ij} \right)$$

Similar tax rates for final demand transactions are computed as follows:

$$FDFSTR_i = FDST_i \,/\, \left(FDD_i + FDUS_i + FDRW_i \right)$$

$$FDOFTR_i = OFT_i \,/\, \left(FDD_i + FDUS_i + FDRW_i \right)$$

$$FDOITR_i = FDOIT_i \,/\, \left(FDD_i + FDUS_i + FDRW_i \right)$$

With the inclusion of these tax rates in the model the tax margin Commodity Indirect Taxes is deleted from the I-O tables used to calibrate the Finance model.

The other tax margins remaining are Subsidies and Other Indirect Taxes. Unfortunately, no information is available which would allow us to allocate these total payments to individual input or output transactions. Consequently the following approach was adopted. A variable $SUBTES_j$ was created, for each manufacturing industry, which is the sum of Subsidies (Commodity 104) and Other Indirect Taxes (Commodity 105). This variable represents the net subsidy which each industry received from the government. It is assumed that this net subsidy accrues to the sector as a per unit output subsidy. The subsidy rate is defined as:

$$SUBTES_j = - SUBTES_j / X_j$$

where X_j is industry gross output. In the I-O tables subsidies are represented by a negative number so that including the negative sign in the above expression treats a net subsidy as positive payment to the industry. This treatment is consistent with the interpretation of the model. The use of the Fortran variable SUBTES to represent both the net subsidy and net subsidy rate may lead to some confusion but hopefully the interpretation of the variable will be clear from the context in which it is used.

A1.10 Other Data Sources

(i) Number of Firms

Data on the number of firms existing in each of the 63 manufacturing industries distinguished in the model were obtained from the Manufacturing and Primary Industries Division of Statistics Canada. The empirical counterpart of a firm in the model is identified as a "long form" establishment as defined in Statistics Canada (1979). Long form establishments represent approximately fifty percent of the total number of establishments and account for approximately ninety-five per cent of the value of shipments in an industry. Given the small size of the other establishments ("small form") in the industry, it was decided that a long form establishment better reflects the notion of a firm or plant used in the model.

(ii) Capital Stock Data

Information on the capital stock employed in each of the 63 manufacturing industries distinguished in the model was obtained from the Science, Technology and Capital Stock Division of Statistics Canada.

(iii) Fixed and Variable Costs

In the calibration program GET, information on non-capital variable costs was obtained from Statistics Canada, *Manufacturing Industries of Canada: National and Provincial Area 1981*, (31-203), 1981. A Value for $g(w,r,q)$ was obtained by summing the industry payments for wages, fuel, electricity and materials and dividing by shipments. The procedure used to impute fixed labour and capital costs is described in Robidoux (1986).

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